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ABSTRACT

This document summarizes the findings of the Learning through Evaluation, Adaptation and Dissemination (LEAD) Center's report on the team approach to the first research experience for undergraduates in botany and zoology. Students (N=25) and faculty (N=12) were interviewed and a comparison was made between students who performed the research in teams and those who conducted their research individually. Qualitative research methods are employed in data collection and analysis and findings suggest that students operate at a more independent level than they are accustomed to. This challenges them and contributes to a gain in confidence. This document is organized into the following sections: (1) Executive Summary; (2) Introduction; (3) The Students' Point of View; (4) The Research Mentors' Point of View; (5) Evaluators' Concluding Remarks; and (6) Appendix: Interview Protocols for Students and Mentors. (DDR)

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LEARNING THROUGH EVALUATION, ADAPTATION AND DISSEMINATION
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ED 412 096

Team Approach in the First Research Experience for Undergraduates in Botany/Zoology 152

Evaluation Report

June 28, 1996

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prepared
for

The Center for Biology Education
University of Wisconsin-Madison

by
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Executive Summary

This document summarizes the findings of the University of Wisconsin-Madison's Learning through Evaluation, Adaptation and Dissemination (LEAD) Center report entitled "Team Approach in the First Research Experience for Undergraduates in Botany/Zoology 152." This summary is primarily intended for those who have not read the entire report, and presents no new analysis.

Background

The Directed Research Project Component of Botany/Zoology 152

Botany/Zoology 151-152 is a two-semester introductory biology course sequence with a second semester option of a directed research project in a faculty mentor's laboratory instead of participating in the traditional course laboratory. During the first semester, students choosing the directed research option investigate potential research mentors and discuss their choices with the course coordinator, who acts as a liaison with the potential mentor. At the beginning of the second semester, directed research students work with their mentor to develop a research proposal and begin their research project. At the end of the semester, students write a final paper and prepare a poster for a collective poster session.

Evaluation of Botany/Zoology 152 Team Research

Doug Maxwell, Plant Pathology, and Jill Patterson, Center for Biology Education, coordinated a pilot program involving Botany/Zoology 152 students who would conduct their research in teams rather than individually. The Howard Hughes Medical Institute provided funds to evaluate the program, and UW-Madison's Learning through Evaluation, Adaptation and Dissemination (LEAD) Center was chosen to conduct an evaluation of the student team research experience in Biology 152.

Evaluation Methods

We interviewed twenty-five students and twelve faculty in the spring and summer of 1995 in order to obtain baseline information. Ten students conducting research in teams and seven students conducting research individually were interviewed mid-semester in fall 1995 and again after they had completed their research projects. Five faculty who mentored teams and four faculty who mentored individual students were also interviewed after the semester ended.

The researchers utilized qualitative research methods for data collection and analysis. The interviews were conducted using a set of open-ended questions, allowing the interviewers to "get inside of" the experiences of the students and faculty. This is to ensure that the experiences and points of view of the participants, not the evaluators, are reported. In practice, this means that the evaluators make an effort to at least temporarily suspend the ideas that structured their interview protocol. The analysis of interview transcripts is focused on determining what is most important to the participants, ensuring that the participants' experiences shape the findings. The primary analytical categories that emerge as the evaluators analyze the transcripts are apparent in the table of contents. In contrast to surveys and other quantitative methods, open-ended evaluations do not yield precise, quantitative assessments of the proportion of participants holding pre-specified opinions. However, open-ended evaluations provide extraordinarily rich information expressing the complexity of the lived experience of the study participants.

The Students' Point of View

In this section we present the students' perspectives on their research experiences during the fall 1995 semester. Team students and students who worked individually shared many of the same experiences in their research projects. Therefore the team or individual category of students is noted only when it was found to be a significant factor in their experience.

Getting Started in the Research Lab

Though students did not report feeling uncomfortable in approaching a potential mentor, most students felt that actually getting started in the laboratory was an intimidating process. They knew very little about the research they were going to do, and felt inadequate compared to the graduate students, post-docs and technicians in the lab. After an initial adjustment period, almost all students felt more comfortable as they began to understand what they were doing, learned lab techniques, and actually began working on their projects.

The Student-Mentor Relationship

Deciding on a project.

The process of acquiring a project was the first substantial interaction between students and their mentors. Students reported a range of experiences in the process of acquiring a project. A few students were naive with respect to their high expectations of what could be accomplished in a beginning research project lasting a semester. Most students felt they had little prior knowledge about the specific research done in the laboratory of their mentor and did not expect to select their projects. Many students reported that their mentors gave them a choice of projects within the framework of the lab's research activities; other students were assigned a project.

Regardless of whether the students had a choice in selecting their project, they experienced different degrees of guidance in designing their project. Most students reported that their mentors did not simply hand them a pre-designed project. Students generally went through a process of learning about the phenomenon and designing specific experiments.

Students had to adapt to the independent nature of working in a research lab.

Many students expected to receive a higher degree of guidance from their mentors. These students thought they would be working more closely with the professor, and instead found themselves acting with a high degree of independence. Therefore, in addition to learning how to conduct their research project, students had to adapt to a new type of learning, one without the usual framework of clear directions and deadlines that they had experienced in course work. Though many students initially expected or felt the need for more direct guidance from their mentors, most of them made a successful transition to working more independently. Students reported that a key factor in adapting to the lack of structure and guidance was developing their knowledge and ability to function in the lab.

After the project was underway, students experienced varying types and amounts of guidance.

Most students described themselves as working largely independently with little guidance from their mentors after getting started on the project, and were positive about the experience they had after the initial period of adjustment. They did not have a regularly scheduled meeting time with their mentors after the project was underway, meeting informally as needed during the semester. In contrast, other students said their mentors provided a greater degree of structure and guidance. A few students who were working on technically difficult projects reported that they needed and received close guidance from lab personnel. About half of the students worked primarily under the guidance of a graduate student, technician or post-doctoral fellow.

Many students established a relationship with their mentors which was different from the customary classroom interactions they had experienced.

Students found the research project to be a unique opportunity to interact with faculty outside of the usual classroom situation. They expressed appreciation for the time their busy mentors devoted to them. A few students discussed establishing a one-on-one relationship with faculty for the first time in their university experience. Some of these found that their mentor took on the role of an advisor with respect to their education and careers and wanted the student to continue working with them.

Students expressed mixed feelings as to whether they felt like part of the lab they were working in.

Students were asked to discuss whether they "fit into the lab" or "felt like part of the lab." A few students reported that their mentors made an effort to make them feel comfortable working in the lab. Many students indicated that they felt like they were part of the lab, and related this to feeling comfortable with other people working in the lab. They thought that the lab personnel were friendly and welcoming, and some students spent extra time in the lab outside of working on their projects. A few students felt ambivalent as to whether they fit in or felt comfortable in their labs. These students focused their discussion on the nature of their interactions with others, or the lack thereof.

A few students did not feel they fit into their labs. Two of these students had expectations about working closely with others, and found themselves not as involved as they hoped they would be. It should be noted that all students thought their research experience was more valuable than regular classroom labs, regardless of whether they felt they were part of the lab.

Team Work

In interviews before the start of their research projects, students expressed varying opinions about the advantages and disadvantages of working in teams.

Students expressed mixed feelings about their previous experiences with working in teams. Many students discussed various problems they encountered with team work in classroom settings, a common complaint being that some team members simply don't contribute. However, most students thought that working in teams had advantages, despite drawbacks. A few students said that working in a team on this research project would be a good experience because they thought that scientists conduct research in teams. A few students indicated that they were not confident enough to do a research project on their own and welcomed the opportunity to participate as part of a team. Others thought that they could combine their skills and share knowledge in a team.

The process of forming the teams.

Most students chose a mentor based on a research area they were interested in and found themselves working individually or in teams, depending on whether the mentor they chose had agreed to have a team. A total of five teams were formed: two teams of three students, and three teams of two students. Except for a pair of students, the students had not met each other before finding themselves starting on the project together. A few students thought it was important for them to be able to choose their fellow team members and did not like being placed together in an arbitrary fashion.

Teams exhibited varying styles of working together.

Teams showed variations in their working styles, from working together on every aspect of their project to cooperating by keeping each other informed and exchanging information. One team of three worked closely together on a single project, planning and sharing the work among themselves. The team wrote a joint proposal, going through a process of making decisions about what they would do in the project, dividing the writing task among themselves, and then combining their work into a final product.

The other team of three students exhibited a different type of cooperation, formulating hypotheses and planning their work together but working in the lab separately. Like the first team, this team also made joint decisions in setting up their project by meeting with their mentor and formulating hypotheses. However, these students wrote individual proposals after the initial meetings with their mentor. They performed their experiments in parallel, rather than together, because their class schedules did not allow them to be in the lab at the same time. The main interaction among the members of the team came during their weekly meeting with the mentor, in which they were expected to take the lead in discussing their work and planning the next steps in the project.

Students who did not often work simultaneously in the lab exhibited several ways of linking together as a team. They reported that seeing each others' experimental results and holding discussions and asking each other questions were helpful. In several instances, a student learned a technique and taught it to another student in the team. Two of the teams kept a joint lab notebook that allowed team members to keep abreast of what the other members were doing.

All students saw some benefits of working in a team.

A few students felt that being in a team helped them deal with their apprehension about being in a research lab for the first time. They appreciated simply having a companion in the lab, a peer they felt comfortable talking with. Students thought that being able to discuss their work and make decisions with the other team members made decision-making easier and lessened their dependence on their mentor. A few students thought that they and their team members had complementary knowledge and abilities, and they benefitted by being able to share these with each other.

A few students saw problematic aspects with working in their teams.

All but one of the students indicated that they were satisfied with their experience of working in their teams. However, a few qualified their expressions of satisfaction with discussions of problematic aspects, centering on the personalities and personal interactions among the team members. One female student did not feel she was able to contribute to the team effort because the two male students in the team did not value her contributions. Two students on different teams felt that the responsibility was not shared equally among the team members, and thought they had to do more of the work.

Students' Views of Their Research Projects

Students uniformly preferred their research experience to science course labs because they felt they were actually doing real science.

Students were uniformly dissatisfied with science course labs, describing them as simulations. They expressed frustration with their Biology 151 labs, feeling that what they were doing was too easy and pre-planned, unlike real science. Many students wanted to do something in which they would actually be making a contribution to science.

Students felt that they were actually doing science in carrying out their research project, and contrasted their research experience with the classroom. One student described the comparison of a science course to research in terms of learning vs. making knowledge. Other students believed they were doing science because their work could help solve real problems and because they were dealing with the unknown. A few students said they had actually found something unexpected.

Students thought that learning in a research project is fundamentally different from learning in a science course. One student described the research experience as "sink or swim" compared to science course labs, explaining that the experience of doing real things in the research lab is a more effective way of learning. A few students remarked how actually doing research makes for deeper and more meaningful understanding when compared to classroom learning, with many saying that they did not get much from science course labs in which they would follow a "cookbook type recipe." Even students who found the research experience extremely difficult thought the experience worth going through.

Students universally thought that their work was meaningful and important.

All students thought their work was of some scientific importance. Many students commented on how they felt their work was relevant to practical concerns, and several felt that it had implications for human health. They did not view their project simply as an educational exercise similar to a science course lab; however, they were realistic in their assessments of what they had done and did not exaggerate its importance. Most students saw their projects' importance and meaning in relation to their mentors' research work: it was meaningful to the students because it was meaningful to their mentor and was within the context of the mentor's lab.

Students described their projects in terms of being tangible or being abstract and generally found tangible projects easier to understand.

Students were able to compare each other's projects in their Biology 152 lab meetings and could see the range of the types of projects they were doing. Most students had projects dealing with visible organisms and generally thought that the theory behind their project was easy to understand and the techniques easy to master. A few students with molecular biology projects felt that the theory behind their projects was complex and difficult to understand.

Students thought the experience of writing the proposal and the final paper was valuable.

Students spent large amounts of time reading the research literature and writing several drafts of the proposal, and most of them thought the process was difficult. A common complaint was they did not know enough about what their research would entail to be able to write the proposal early in the project. Because of the changing nature of their project, a few students handed in incomplete proposals or delayed handing them in until later in the semester. Though students found writing the several drafts of the proposal difficult, they almost universally expressed approval of the task.

Students received varying degrees of assistance from mentors in writing the proposal. Mentors at the very least read and commented on a proposal draft and a few mentors worked more extensively with students. In general the mentors made relatively few comments on the students' draft, leading students to believe that the proposal was at least sufficient. Many students were surprised to get their proposals back from the course coordinator with numerous corrections and suggestions for revision.

Students had mixed views on the value of the peer reviews of their proposals. A few students were helped by having other students comment on what they wrote, but most did not think that having other students read their proposals assisted them. A common observation was that the students did not know enough about each others' research area to offer constructive comments. However, many thought that reading other proposals was helpful to them.

Students saw the value of writing a final paper, but they had mixed feelings about the poster session. Several students were enthusiastic about it, expressing pride and thinking the session important and enjoyable. Other students were ambivalent or negative about having to prepare a poster and present it at the poster session, their most common complaint being a lack of interested viewers.

What Did Students Gain from their Experience?

Some of the benefits that students gained from working on their research projects, such as being able to establish a one-on-one relationship with a faculty member, have been discussed throughout the executive summary. This section reports the students' perceptions of other benefits they received.

Students gained an understanding of how scientific research is actually conducted and a glimpse of the varieties of research on campus.

Students received their first glimpse of scientific research in real settings and many students talked about the importance of being in a real research lab in a holistic sense, not simply in terms of their own project. Students gained an understanding of the scope of research on campus and the different possibilities available to them in research, both now and in the future.

Students experienced the day-to-day reality of working in a research lab, and the responsibility and commitment of doing research. They gained a more realistic sense of the amount of time it takes to get research results, and found that the actual practice of doing research was complex in comparison to the theoretical scientific process that they had learned about in the classroom.

Most students reported that they gained confidence in their ability to do research.

Students found that even though they did not initially know much about their mentors' research, they were able to develop their knowledge and abilities, and function in the lab. Students who were interested in research prior to their experience uniformly reported that they now felt that they have the ability to succeed in research.

The research experience provided students with the opportunity to envision themselves as going into research and aided them in deciding whether to pursue a research career.

Many students discussed how as a result of this research experience they could now envision themselves doing research as a career. Students became aware of different career possibilities and saw their experience as opening opportunities for them. Students' relationships with their mentors were important in their feeling that they could find a place in research. As noted earlier, a few students commented on how their mentor made an effort to make them feel comfortable in the lab, and others commented about establishing a one-on-one relationship with a faculty member for the first time in their university experience. A few students looked upon their mentors as role models and identified with them.

A few students were able to confirm their earlier beliefs that they were interested in a science career. Other students said that their experience not only confirmed their interest in a science career, but helped them realize that they were interested in the research area of their project. Most of the students expressed an interest in doing more research as undergraduates. A few students came to realize that they were not interested in pursuing a research career in the area of their project. Even though these students found that they were not interested in doing research in the area of their project, they thought their experience valuable.

The Research Mentors' Point of View

In this section we present the research mentors' descriptions of their experience during the Fall 1995 semester.

Mentors' Goals and Motivations

Mentors universally wanted students to learn how to think like a scientist as part of their general education and to prepare them for citizenship.

All mentors expressed variations on the theme that learning how to think and act like a scientist is valuable for the individual and for society. They thought that even if students decide science is not for them, the experience is still a positive part of their education. Many mentors thought that the research experience teaches students universally applicable problem-solving skills, valuable in all fields. They believed that it is a "very useful kind of paradigm," one that can apply to "just about any problem you encounter."

Mentors felt that students lack contact with faculty at large research institutions such as UW-Madison, and the research experience addresses this situation.

A few mentors spoke of the impersonal nature of a large campus, with one mentor commenting that some students never have the opportunity for personal contact with faculty. One mentor thought that there isn't enough undergraduate research at UW-Madison and felt its sheer size hampers students from understanding the resources that are available to them. Another mentor believed that offering a research experience is a strong suit of a large research institution like UW-Madison and that doing research can make attending a large campus a more personal experience for students.

Mentors thought that the projects gave students an opportunity to gain an understanding of how science works by actually doing science.

Mentors thought that having students simply see research labs in operation was valuable in itself, and stressed the distinction between research and classroom science. Mentors thought that the research experience showed students the day-to-day realities of doing research; a few mentors commented that students needed to see that research sometimes involves long hours of repetitive work. They believed that the experience would make science and scientists less mysterious and intimidating to students and help them see scientists as people.

Mentors view the research experience as a way of bringing students into science.

Underlying many of the mentors' motivations is the desire to have students become interested in going into science as a career. Mentors viewed the research experience as an entree into science for students that the classroom can't provide. A few mentors mentioned that their undergraduate research experience was critical to starting their careers. These mentors' own undergraduate research experiences were a motivating factor in their offering students a place in their labs. Mentors who had long-term experience with undergraduates working in their labs spoke of how students develop an interest in science through exposure to the laboratory. Though mentors were interested in developing future graduate students, they realized that the chance of a given student going on to graduate school is low.

Mentors believed that their graduate students learn about teaching by guiding undergraduates' research projects.

A few mentors mentioned the value to graduate students of guiding an undergraduate student's research project. They thought it was an important part of their graduate students' education, and saw their mentoring as a dual process of teaching both their graduate students and the undergraduates.

Role of the Mentor

Many mentors saw the need to make their students feel comfortable and fit into the lab.

Mentors felt that students in general are initially intimidated by being in a research laboratory for the first time and need to go through a phase of adapting to the laboratory environment. They thought that students are hesitant to ask questions and are afraid of making mistakes and failing. Some mentors invited their students to make the lab a place where they could come to socialize or to study, offering the use of computers. A few mentors expressed mixed feelings about whether their students felt that they fit into the lab, while other mentors thought that their students had adjusted to the lab and felt comfortable.

Mentors varied in how they involved students in the selection of a research project.

Mentors varied from assigning a project to students to giving them a limited choice of projects that would be appropriate for their labs and for the students. Whatever the method of selecting a project, many mentors had students decide what they wanted to investigate about the phenomenon and how to go about doing it, rather than laying out the details of the project for them.

Most mentors tried to select projects that would be suitable for their inexperienced students.

The research areas in the mentors' laboratories ranged from working with visible organisms to molecular biology. Many mentors thought that students should have a project involving a question that could be fully investigated in one semester. These mentors thought that students should have a sense of completion at the end of the semester.

A few mentors working in molecular biology discussed the problematic aspects of designing a project in their research area that was suitable for a one-semester first research experience. They described projects in molecular biology as generally involving complex techniques and being incremental in nature, with one mentor commenting that projects in this area often limit students to learning techniques rather than testing a hypothesis.

Mentors provided different ways of structuring the students' research experience.

Mentors spent time with the students, assisting them in getting started on the project. After this initial phase, most mentors had the students work largely independently of them. Most mentors did not discuss specific goals or a schedule with the students and allowed students to work at their own pace.

Mentors generally had the students work with a graduate student, technician or post-doctoral fellow after the introductory phase of the project was completed. They viewed their role as one of overseeing rather than closely monitoring their student. Aside from mentors' belief that mentoring was beneficial to their graduate students, the shared mentorship seemed to be necessitated by the work load of the mentors: they simply did not have time to guide students in the day-to-day lab work.

Many mentors structured the projects through hypothesis formation and testing. But a few mentors pointed out that molecular biology projects are sometimes difficult to structure in terms of hypothesis formation and testing, with one commenting that testing hypotheses is "more than can be accomplished in a semester."

Mentors' View of Students and their Research

Most mentors viewed their students in a positive light and were pleased with their effort.

Most mentors praised their students, describing them as having mastered the techniques necessary to get results. Many mentors thought that their students performed exceptionally well. Two mentors indicated that they had students with whom they were not pleased. One of them did not think the student made a sufficient effort. The other mentor expected his student to know far more than the student did, thinking that "he could step in and begin to do things in the lab."

Mentors believe that responsibility, commitment, and curiosity are key student characteristics for success in the research lab.

Virtually uniformly, mentors brought up responsibility, commitment, and curiosity as the characteristics they considered essential for a student to be successful in the laboratory. A few mentors took the characteristic of curiosity a step further, wanting students to be interested in their area of research. The importance of scientific knowledge and intelligence were downplayed by almost all mentors.

Mentors had differing descriptions of the scientific value of their students' work.

Mentors universally characterized their students' work as actually doing science rather than simply carrying out an educational activity as in a science course lab. A few mentors reported that their students found something unexpected. However, most mentors do not expect publishable data from their students' work. Despite this, many mentors felt that the students' research was a valuable initial investigation that would be worth replicating.

Most mentors felt that when measured strictly by research results, mentoring undergraduates is costly in terms of their own and their lab personnel's time.

In discussing this issue, mentors were speaking of their past experience in general, rather than commenting on their current Biology 152 students. Mentors felt that mentoring has a cost, and measured the cost in terms of their own and their graduate student or lab technician's time. Most felt that the research results the undergraduates produce were expensive in terms of time and were sensitive to the demands on their graduate students.

Mentors said they were extremely busy with their teaching, research and administrative responsibilities, and two of them expressed some degree of guilt in mentoring undergraduates. Many mentors spontaneously brought up the pressures they are under to get research results which will ensure career advancement and further funding of their labs. They felt these pressures made it difficult to mentor undergraduates, and two untenured mentors remarked that mentoring will not advance their prospects for tenure.

Though mentors do not think the undergraduates' research results are worth the time and effort in the strict sense of producing publishable data, they will continue to mentor students because they gain personal satisfaction and have broader educational goals. They do not see the issue as one of cost/benefit in a strictly economic sense but believe that the value of mentoring lies in the other areas that have been previously discussed under Mentors' Goals and Motivations.

Mentoring Teams

Five faculty members agreed to mentor teams. When contacted prior to the beginning of the semester, they expressed an interest in working with a team of students. They thought working in teams was a common research practice and expected the team experience to work well.

Mentors described several ways in which their students benefitted from working in a team.

Mentors said that the students in teams offered support to each other, which made the experience less intimidating. Students in teams were a "buddy system" and helped each other find their way through the experience, relieving the mentor of some responsibility. Being in a team made students feel less intimidated about interacting with the mentors. Mentors reported that one student learned a laboratory technique and subsequently taught it to others. Most mentors thought that the students accomplished more together than they could have individually, with one remarking that his team of three students had complementary skills.

Almost all mentors were positive about their experience with students working in teams.

One mentor was enthusiastic about his experience, saying "I'd do it again in a heartbeat." Others thought that working with a team was more efficient in terms of their time compared to working with the same number of individual students. One mentor even thought that working with three students was very efficient, possibly taking no more of his time than an individual student. None of the mentors indicated that they would be hesitant to mentor a team again.

Some potential mentors did not want to mentor teams, citing the pressures of their work loads.

Six faculty members were asked if they would mentor teams and declined the opportunity to do so. Several of them couched their discussion of why they did not want to mentor a team in terms of the pressures they are under to get research results. One faculty member didn't see any advantage of students working in teams, explaining that he feels it necessary to pair undergraduates one-on-one with a graduate student. Though these faculty members saw the benefits to undergraduates of having a research experience, the pressures of their work loads were too much for them to consider the responsibility of mentoring a team.

Mentors' Views on the Proposal and Poster Session

Mentors felt writing the proposal was essential for students to understand what they were doing.

Mentors felt that proposal writing helped students understand the nature of scientific research and their project. One mentor said that students need to gain an understanding of the central question in order to see why they are conducting experiments. Writing the proposal is an excellent way of assisting them in gaining this understanding. Mentors generally did not actively direct the students' work in writing the proposal, but simply commented on drafts of the proposals.

Mentors felt the poster session provided students with a positive experience.

Several mentors attended the students' poster session. Though most mentors were not involved in producing the poster, they thought that the poster session provided the students with a positive experience. A few mentors described how proud their students were of their poster. One mentor believed that the poster session helps give students a sense of closure and accomplishment even if their project did not reach firm conclusions.

Evaluators' Concluding Remarks

The students who participated in the directed research component of Botany/Zoology 152 described varied experiences that differed with respect to the nature of the projects they worked on, the laboratory culture they experienced, and the degree and type of guidance they were offered by mentors. Despite these variations, the students were unanimous in the belief that their research project was a valuable experience for them, and all termed it a success. Even the few students who experienced considerable difficulty with some aspect of their research project indicated that they did not regret their choice to conduct research rather than take the traditional course lab.

Students judged their research experience in relation to traditional science course laboratories. They reported that they experienced the real world of scientific research for the first time, and found it to be richly rewarding and far superior to science course laboratories. Students overwhelmingly felt that this experience enhanced and broadened the scope of their learning, particularly because it did not involve pre-planned experiments or simulations. They found themselves operating at a more independent level than they were accustomed to, and this challenged them and contributed to their gaining confidence.

We examined several components of the research project, including:

- the nature of the research project
- level of guidance from faculty
- interactions with peers, graduate students and others in the lab
- Botany/Zoology 152 lab meetings
- team versus independent work
- the team's organizational structure and working style

These components obviously did structure the particular experiences of individual students and might reasonably be expected to exert an effect on their perceptions of success. However, we could not perceive any strong patterns which would lead us to conclude that a particular variation within a given component was a determining factor in a successful research experience.

The evaluation's broad initial questions concerning team research were stated as follows:

- What is the nature of the team experience for undergraduates and faculty?
- Are there any characteristics unique to the team approach which are linked to success?

Because of the students' near-uniform perceptions of success and value, despite their differing situations, these initial questions did not receive simple answers. The nature of the team experience for both students and faculty varied considerably, with students within a given team offering differing perceptions. Teams varied in their organizational structure and working styles, and faculty mentors displayed different mentoring styles. Though team students and their mentors could cite advantages to the team approach, we found perceptions of success to be similar among team and individual research students. However, it should be noted that we are basing this finding on interviews with ten students from five teams and seven students working individually. Further study involving more team and individual students would be needed for confirmation.

Introduction

The Directed Research Project Component of Botany/Zoology 152

Botany/Zoology 151-152 is a two-semester introductory biology course sequence at the University of Wisconsin-Madison. The course consists of a lecture section meeting three times a week, and one three-hour laboratory, carrying a total of five credits. Both 151 and 152 are offered each semester. Beginning about 15 years ago, students in 152 were given the option of doing a directed research project in a faculty mentor's laboratory instead of participating in the traditional course laboratory. The number of students choosing the directed research option has increased and is now about 40 - 50% of the class each semester.

Students are presented with this option in the latter part of the 151 semester. They are told that the research project entails developing a research proposal and conducting research for ten or more hours per week. If they choose the research option, their first step is to visit departments of interest and obtain lists of faculty and their research areas. The students can choose laboratories from the wide variety of biological research that is conducted in several UW-Madison Colleges and Schools, including the College of Agriculture and Life Sciences, College of Letters and Science, Medical School, School of Pharmacy, as well as several research centers on campus. When students have drawn up a list of potential faculty mentors, they arrange a meeting with the 152 course coordinator to discuss their choices. The coordinator then contacts one or more potential mentors to attempt to arrange a match between the mentor and the student.

As the students' research semester begins, they initially work with their mentors to develop a research proposal and meet for three 152 lab periods to acquire information about conducting a literature search and writing a proposal. After the initial three meetings, the 152 lab periods meet about every three weeks. As students develop their proposals with the assistance of their mentors, the proposals are reviewed by the 152 course coordinator, their teaching assistant, and their fellow students. Near the end of the semester, students write a final paper and prepare a poster for a collective poster session. The paper is in a standard scientific paper format and includes the following sections: Abstract, Introduction, Materials and Methods, Results, Discussion and References. Students whose research is incomplete at the end of the semester submit an "interim report." On a 100 point scale, students receive a possible 30 points for progressing through the proposal review and re-writing stage, 30 points for the final paper, and 40 points from their mentor's evaluation. Students receive one credit of independent study in addition to the normal five credits for 152.

The Evaluation of Botany/Zoology 152 Team Research

The Howard Hughes Medical Institute has awarded the UW-Madison a four-year grant to improve undergraduate education and outreach programs in the biological sciences. One portion of the grant is devoted to supporting the directed research component of Botany/Zoology 152, and included funds to evaluate a pilot program involving students who would conduct their research in teams rather than individually. Doug Maxwell, Plant Pathology, and Jill Patterson, Center for Biology Education, coordinated this pilot program with the idea that a cooperative team approach to research might make for a more successful first research experience. Evidence from the work of Uri Treisman, Texas, and the UW-Madison Wisconsin Emerging Scholars Program indicate that mathematics students working in group settings can work at a higher level of difficulty, have more confidence, and continue on in advanced courses at a higher rate than students who work alone. In March 1995, Maxwell and Patterson contacted potential mentors for the student research teams and received a number of positive responses from faculty who were willing to work with teams. Five faculty were selected to guide teams of 2 or 3 students during the fall 1995 semester.

The University of Wisconsin-Madison's Learning through Evaluation, Adaptation and Dissemination (LEAD) Center was chosen to conduct an evaluation of the student team research experience in Biology 152. The evaluation team consisted of Baine B. Alexander, the Associate Director of the LEAD Center, as project director; Lyman Lyons and Judy E. Pasch of the LEAD Center as researchers; and Jill Patterson of the Center for Biology Education as researcher. The broad initial evaluation questions were stated as follows:

- What is the nature of the team experience for undergraduates and faculty?
- Are there any characteristics unique to the team approach which are linked to success?
- Why are certain research experiences successful and others unsuccessful?

The evaluation team would probe as to whether the students and faculty believe that research had an effect on students in such areas as:

- understanding the scientific research process
- career goals
- seeing themselves as having a place in science
- becoming motivated to continue in research
- working cooperatively in a research team
- acquiring confidence
- educational outcomes: knowledge, cognitive skills, attitudes

The effect of various components of the research experience would also be studied, including:

- characteristics of the research project
- level of guidance from faculty
- interactions with peer, graduate students and others in the lab
- Botany/Zoology 152 lab meetings
- team versus individual work
- the team's organizational structure and working style

Evaluation Methods

The LEAD Center began the evaluation by conducting baseline interviews in spring 1995 after the Botany/Zoology 151 students had selected their laboratory option for the following semester, fall 1995. A total of twenty-five students from the following categories were interviewed:

- students who would conduct research in teams
- students who would conduct research individually
- students who would be in the traditional Botany/Zoology 152 laboratory sections

Students were asked to discuss their reasons for choosing either the research option or the traditional 152 laboratory, their thoughts on working in a team, and their expectations and goals for either research or the traditional lab. Because this was a spring, rather than fall, semester offering of Biology 151, relatively few freshmen were enrolled. Most of the approximately seventy students who chose to do research projects were sophomores and would be juniors the following semester.

Baseline interviews were conducted in summer 1995 with a total of twelve faculty from the following three groups:

- faculty who would guide a team
- faculty who would guide an individual student
- faculty who had declined the offer to guide a team

Faculty were asked to discuss their motivation for mentoring undergraduates, how they would guide the students, and their thoughts on undergraduate researchers working in teams. (Note: all interview protocols for students and faculty are in the Appendix).

Using information from the baseline interviews to design new interview protocols, LEAD Center researchers interviewed ten students conducting research in teams and seven students conducting research individually in the fall 1995 semester. Students participated in two interviews: one at mid-semester fall 1995 and one after they completed their research projects. Five faculty who mentored teams and four faculty who mentored individual students were interviewed after the semester ended.

The researchers utilized qualitative research methods for data collection and analysis. The interviews were conducted using a set of open-ended questions, allowing the interviewers to "get inside of" the experiences of the students and faculty. This is to ensure that the experiences and points of view of the participants, not the evaluators, are reported. In practice, this means that the evaluators make an effort to at least temporarily suspend the ideas that structured their interview protocol. The analysis of interview transcripts is focused on determining what is most important to the participants, ensuring that the participants' experiences shape the findings. The primary analytical categories that emerge as the evaluators analyze the transcripts are apparent in the table of contents. In contrast to surveys and other quantitative methods, open-ended evaluations do not yield precise, quantitative assessments of the proportion of participants holding pre-specified opinions. However, open-ended evaluations provide extraordinarily rich information expressing the complexity of the lived experience of the study participants.

Technical Information

Use of Verbal Quantifiers in Reporting Qualitative Data

Specific verbal quantifiers are used to denote the relative size of a group of participants who presented particular perspectives or described particular experiences in interviews. It is important to note that due to the nature of qualitative interviews, the size of a group that *discussed* a particular type of experience does not indicate the size of the group who *had* this type of experience. Although the same interview protocol was used in each interview, respondents' answers often prompted discussion on a particular area that may not have emerged in other interviews.

The verbal quantifiers used in this report are:

"a few":
used when up to 30% of those interviewed presented the perspective under consideration

"many":
used when 30 to 60% of those interviewed presented the perspective under consideration

"most":
used when more than 60% of those interviewed presented the perspective under consideration

"almost all":
used when there is near unanimity on the perspective under consideration

Presentation of Transcribed Materials

Interview dialogue is marked “I:” to indicate an interviewer's speech and “R:” to indicate the speech of the student or faculty respondent. A row of asterisks separating two or more quotes indicates that different interviewees are represented in the quotes. Ellipses (...) in quoted material indicate deleted dialogue occurring within the reproduced material. Deletions are made so that readers can appreciate the speakers' views on a particular topic without having to sort through the divergent twists and turns of the raw dialogue. Explanatory words added to quotes appear inside brackets [ ]. The quoted material is presented as faithfully as possible to the speaker's intent.

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The Students' Point of View

In this section we will present the students' perspectives on their research experiences during the fall 1995 semester. The main headings and sub-headings represent themes uncovered by our analysis of the students' interviews. Some of the themes arose from student responses to our interview questions. Other themes were brought up and discussed by the students without prompting by the interviewer. We interviewed ten students working in teams and seven students working individually in the middle and at the end of their research. Team students and students who worked individually shared many experiences in their research projects which did not seem dependent on whether they worked in a team or individually. Therefore, the team or individual category of students is noted only when it was found to be a significant factor in their experience.

I. Getting Started in the Research Lab

A. Students went through various processes to locate a research mentor.

Many students visited several departments to find out which faculty members were doing research in their areas of interest. After identifying one or more possibilities, the students explained that they had the Biology 151-152 course coordinator make contact with a potential mentor to arrange an interview.

> Well, we were told to do it, that you had to go and look through the timetable and find the different biology or biological science department that interests you. And then, it was kind of an independent thing that you had to go do, you had to go then to the different department chairs' offices and ask them to list different professors in that area and their areas of research. And so then I got those and then I went through and I found different labs that sounded appealing to me, and then I gave that list to [course coordinator] and then she actually did the calling or whatever and then I got put in my lab.

Other students simply found a mentor through the laboratory without doing an investigation on their own. Though the process of finding a mentor involved some work for most students, none of them reported feeling uncomfortable or intimidated in approaching a potential mentor. Students located mentors at different times: some by the end of the spring semester, others not until after the beginning of fall classes.

Two students reported that their mentors misunderstood the nature of the students' research project. One mentor thought that the student would be in the lab for only a few weeks, and the other mentor was under the impression that the student had considerable laboratory experience. The latter student underwent the uncomfortable experience of failing to live up to expectations of the mentor and his lab personnel before the situation was clarified.

B. Most students reported that getting started in their mentor's laboratory was an intimidating process.

1. Most students knew very little about the research they were going to do and felt inadequate compared to the graduate students, post-docs and technicians in the lab. The students were starting from scratch, being unfamiliar with the equipment and techniques. One described himself as initially being afraid because of his lack of knowledge, and considered dropping the research project.

> Initially I was scared out of my gourd. I was like, "Oh my God! Why am I here? I shouldn't be doing this. I should just drop it now."
>
> **************************
>
> I went in there going,"I don't know what I'm doing." You know, it was like being thrown into something that I had no clue. [The mentor] has been working for lord knows how long. [The technician] has been doing it, and there's a grad student and an undergrad working in the lab also. It was intimidating going in there because I was like, I have no clue what I'm doing.

Another student feared making destructive mistakes.

> I was worried about, just that I would be doing something for someone's lab, and just screw it up and destroy someone's research, and I was worried.

2. A few students felt comfortable from the beginning and didn't think that getting started was stressful.

> Actually, everyone was really friendly, really open. Everyone was really ready to answer any of my questions, so it made it easier. And I asked questions so I didn't have to later on. The lab was really great. They taught me the basics, and then I just kind of went on from there.

3. Getting to know the other lab personnel was an important factor in students becoming comfortable. Many students reported that they were initially intimidated because they didn't know the lab personnel and were afraid to disturb their work.

> Yeah, I didn't know what was going on and I also felt like I didn't want to bother the grad students. You know, when they're doing their science experiments you want to keep out of their hair.
>
> ***********************************
>
> I didn't know the people in the lab and I mean these people are all a lot older then me, I mean they're all post doc's and everything and I'm like, hey, I'm a sophomore. But, it was, the whole atmosphere was so intimidating to me so I think I was a lot more reserved.

Students said that they became more comfortable being around and working with the lab personnel, and a few students came to regard the lab as an enjoyable place to be.

> But now I mean, I know everybody and I like just going there and talking to people. It's really interesting to hear because there's different people in the lab working on different things, so I get to see like the whole scope of the project and I think it's kind of neat.

4. After an initial adjustment period, almost all students felt more comfortable as they began to understand what they were doing, learned lab techniques and actually began working on their projects. Students experienced a period of adjustment during the initial phase of working on their project. As they developed their knowledge and abilities, almost all students began to feel more comfortable with their project and with working in the lab environment.

II. The Student-Mentor Relationship

A. Deciding on a project.

The process of acquiring a project was the first substantial interaction between students and their mentors. Students reported a range of experiences in the process of acquiring a project.

1. A few students were naive with respect to their high expectations of what could be accomplished in a beginning research project lasting a semester.

> When I first went in to write my proposal and what not, talking to [the mentor]. Ah, I was under a misconception, that's another thing it taught me, it was a misconception that I could basically perform this whole experiment in one semester. Like construct it and put it into the animal to see if it works. So that was my proposal, to construct the vaccination plasmid and put it into the animal and test the animal also for its resiliency and see if it works. As it goes, there's no way, that'd probably take a couple years. [Laughter] Coming into it I was like, yeah, it'll be cool, I'll make this thing in a week and then I'll stick it in there and it'll be a nice little experience.

2. Most students felt they had little prior knowledge about the specific research done in the laboratory of their mentor and did not expect to select their projects. One student's statement, "I mean, I didn't even know what they were working on at first," was a common experience. Students expressed a willingness to accept what their mentors thought would be a suitable project for their investigation.

However, two students had ideas of what they wanted to work on. Both students found that their original ideas were not realistic, and ended up following their mentors' suggestions. One of these students explained the problem with her original idea and how she and her mentor decided on a different project.

> I had originally had a different idea and we decided it wouldn't work. So, he gave me this other idea and was like, "Well, you could do something like this." And so then I kind of sat down and I thought about it, and was like, "Well, what if I like expanded on this idea and did this?" And he was like, "OK, you can do this by doing this." So I had originally

> wanted to do um, sort of like sexual aggression between new pairs of primates and we decided that it wouldn't work because you don't know when they're going to copy it or when they are going to have sexual interaction. So we decided it wouldn't work, so we decided to do something with socialization of parents. And I decided, well what if we did it with the different number of infants, and then he kind of helped me set up how I should do it.

3. Many students reported that their mentors gave them a choice of projects within the framework of the lab's research activities; other students were assigned a project. Many students found that their mentors did not have a specific project in mind, and they were presented with more than one possibility that fit with the lab's research.

> Actually, Professor _______ came up with some ideas and he said, well, we have this and this that we want done. He basically gave me choices.

Other students found that their mentors had selected a project, or at least a specific phenomenon for them to investigate.

> Well Dr. ______ at first, he presented - there's two different ways we could've gone with the project, and then he basically assigned the project to us. I mean it wasn't like, hey I want to do this because it works into what they're doing. So he basically came up with it and told us that we were each gonna be doing this area.

One team of students reported that their mentor gave them readings on the basic phenomenon he wanted them to investigate, and they picked one of the options he had suggested.

> When we first met, us three met with [the mentor] and [the graduate student], and the two of them explained about the gypsy moth, about the wasp. . . Then [the mentor] indicated a couple of different things that he thought would make good experiments for us to do, given our level of knowledge. He gave us a couple of options for what he thought we could handle, and then I think we agreed to meet like in the beginning of the semester, and then he gave us some articles to look up--journals--just general background information. Then we set up a meeting the following week. The three of us had gotten together during that week after we had done the articles, and uh, just decided on one of the options that [the mentor] had given us.

4. Regardless of whether the students had a choice in selecting their project, they experienced different degrees of guidance in designing their project. Students reported that their mentors generally did not simply hand them a pre-designed project. Most students, regardless of their degree of choice in deciding on their project, went through a process of learning about the phenomenon and designing specific experiments.

> I: O.K., so you had some choices?
>
> R: Right, and then I chose from that. But then I had to come up with the experiment and

> stuff. I used, like, [the graduate student's] old research and what he had done to inoculate the plants, you know, what procedures he had used and stuff, and I just kind of gathered information and put my experiment together by doing that.

One team of three students found that their mentor had decided they would work on cortical contraction in frog eggs, but they had to decide how to investigate the phenomenon and formulate their own hypotheses.

> He gave us these readings on cortical contraction... and we went in for the first meeting with him, and he sort of let us - he didn't tell us what we were going to do, but he asked us - he's like, "O.K. you want to know this, what would you do?" He talked to us - we talked through it, and we came up with three hypotheses, and then it was just a matter of running experiments to test them. It was - you know, he helped us, but he didn't feed it to us, which was good. I mean, he made us work for it. He made us actually sit down and actually think about it and comprehend how we could possibly run the experiments to try and prove what we were trying to prove. It was very good in that manner.

B. Students had to adapt to the independent nature of working in a research lab.

1. Many students expected to receive a higher degree of guidance from their mentors. These students thought they would be working more closely with the professor, and instead found themselves acting with a high degree of independence. One student's mentor followed a practice of continually asking questions and guiding only indirectly, and the student initially found the independence and self-direction difficult and time-consuming.

> It's actually - it's harder than what I expected. I guess I expected the professor to be there leading me by the hand, showing me, "O.K., this is what you do, do this," whereas it's, "O.K., if this is what you want to do, do it." Or, "What do you want to do? Talk to me, tell me about it," you know. He makes us think for ourselves, he doesn't - he doesn't spoonfeed us. It's a lot more difficult than I thought it was, and it's time consuming. It's something that you really have to spend time doing, and it's hard to - I mean, for me especially it's hard to juggle it because I've got some really difficult classes this semester.

This student went on to discuss the experience of learning a difficult technique early in the semester alone in the lab after others had gone home.

> R: Yeah, squashing them, couldn't get the follicle cells off - it was not a pleasant experience. But you get used to it, you learn the technique, you get it down. The same thing with micro-injection. It's like, I can micro-inject things like that now, it's just a matter of going in, just setting it up, do, do, do, whereas like the first time it was like the most hellish experience I've ever had in my life!
>
> I: Really? That bad?

> R: It was nasty. I got very frustrated. That was the night that I was there for like 9, 10 hours. It was frustrating! I couldn't seem to get it down, I couldn't get the needle to go in the stupid thing. It got very, very frustrating, but it was, I guess, a learning experience, 'cause you get it down, and now I'm fine with it.

2. In addition to learning how to conduct their research project, students were adapting to a new type of learning that was different from their experiences in coursework. Though many students initially expected or felt the need for more direct guidance from their mentors, most of them made a successful transition to working more independently. One student described her successful adjustment to not having the usual course-related framework of clear directions and deadlines.

> I kind of expected it to be more. . . I guess more structured. I guess not so much independent. This is what I expected. I like the way it is now. Like I'm happy it's not as structured as I thought it was going to be. And so that's another problem I had in the beginning - I don't have anyone that's like, "O.K. you have to do this by now." You know, like "You have to have this done." You know, "Go do this, hand it in tomorrow." You know?

Students reported that a key factor in adapting to the lack of structure and guidance was developing their knowledge and ability to function in the lab.

> It is just becoming more familiar with the lab environment. That entails everything I think--in terms of the methods, you become better at doing those. In terms of the people, you get used to working with the people there. The amount of stuff you learn about the material increases almost exponentially as you get into your work, and start reading the papers, start understanding them. So in that sense, yeah, you do become very much adapted. It's a progressive development in the lab, absolutely.

Many students said that attaining some level of expertise was needed for them to overcome their initial intimidation and successfully make the transition to working independently.

> Once you start doing it you get used to it, you get the language down and everything. It all goes together, and you get really comfortable with it....and I feel real comfortable now in the lab. I mean, I feel like I actually know something and I know what's going on and I can comprehend what I'm doing, whereas when I first went in I was very shaky.

C. After the project was underway, students experienced varying types and amounts of guidance.

1. Students reported that mentors used different types of organization and planning in providing guidance. Most students did not have a regularly scheduled meeting time with their mentors after the project was underway. They and their mentors generally met informally as needed during the semester.

> We saw each other enough to, I mean, we didn't have regular meetings set up, but her office is set up right next to our room, so, whenever she'd come by, we'd stop and talk.....I don't know, once a week, once every two weeks. It depended on what we found, you know? If we found something that she'd never seen before, like stomatas over crystals all in a row, or something, then she'd sit down and she'd look at it and get all excited and think, "OK, now what do we do?"

One student described the open-ended approach to research design that her mentor used, in which the mentor gave directions based on what the student was finding.

> We're just kind of winging it in what we find. And after we do a batch then pretty much she tells us, "Well, then try this. And then try this. And find some more of those." And that kind of thing.

In contrast, other students said their mentors provided a greater degree of structure and guidance. One team of students reported that their mentor helped them draw up a timeline for the semester so they could accomplish what they had planned in their project on a gypsy moth parasite.

> A few weeks ago we sat down and we just looked at the calendar and said, by this week we should have this all set up, then by this week we should be counting.

However, most students reported that their mentors did not organize their semester or structure their work in the sense of creating timelines.

> Yeah. Everything wasn't written down. Everything wasn't written, formulated, set, do this. . . It was unstructured. I mean, it wasn't unstructured, but it wasn't all down on paper. It wasn't all ground into stone, this is how you do it. . . Julie and Bill would be like, okay, do this. They'd tell me, and I'd be like, "Ooooh, how do I do that?" at the beginning. It was a lot - it wasn't structured. But that was definitely beneficial. It wasn't all planned out for you where all you needed to do was open your eyes and have a pea-sized brain and go to it.

Three students in one team described a type of guidance that differed from other students' experiences. Their mentor continually guided them in the sense of being supportive and helping them frame their research questions, but refrained from directly instructing them on what to do. The mentor was in the lab much of the time but let the students work at their own pace without detailed directions from him.

> R: I mean he's usually at the lab all the time while we're there. And he comes in and sees how things are going. But, I mean we don't really sit down and have one to one conversations.
>
> I: You mean once or twice a week?

> R: Well, he usually - like you know, say I'm in there Monday and Wednesday afternoons. He's usually in there a couple of times each afternoon or whatever. And then if I walk out you know, to go get something he's like, "How are things going?"

The mentor, unlike most, had regularly scheduled weekly meetings with the team. One student described the mentor as encouraging them to lead the discussion and make decisions at their weekly meetings, rather than offering overt direction.

> Well basically we have - every Friday we have little group discussions and so we get together, we discuss what we've done, and then as the point we did two weeks ago, "OK where do we go next?" And so we did this - I mean [the mentor] gave us little pointers and tried to get us going in the right direction. And we're like, "OK, well it's got - the PKC has got to be doing something. You know, what is it doing?"

****

> Yeah. He sits in on our meetings and he guides us to the next step if there is a next step or we talk about what we've done. And he usually likes us to go up to the blackboard and put our results down and he likes us to be the ones doing the talking.

One student in this team reported that the mentor told them, "It's your project, make it that," which encouraged them to take ownership of the project. He thrived under the type of guidance the mentor provided.

> R: It's less - I don't want to say less guided, but it's more.. it's just more independent, I think.
>
> I: Do you feel comfortable with that level of guidance?
>
> R: Yeah, I feel - yeah, I feel very comfortable with it actually. I'm sort of impressed because - like, I went in one day for six hours and I just ran my experiment, I did whatever, and I didn't have to go to anybody and say, "Am I doing this right, is this okay, is this how you do this?" It was more of my own interaction. I can do what I want. And then when I was leaving he asked me how it went, and I told him. He's like, well, it sounds like it went good. You know, the encouragement and the help is there if I need it, but if I don't, they aren't constantly always harping all over me, making sure it's what they want.

2. Most students thought that they worked largely independently with little guidance from their mentors after getting started on the project, and were positive about the experience they had after the initial period of adjustment. One student, an extreme case, described herself as functioning independently of her mentor or any other people, initiating contact with her mentor as she needed.

> I'm basically doing it on my own. . . In the beginning we probably met like, probably about once, maybe twice a week. I went over my proposal and ideas I had, and what I really wanted to do and how we were going to do it. And now I just basically have been

> doing it on my own. And meet with him now and then, like he's constantly in and out of the lab. I mean he's not around a lot because he's a very busy man. And so when I get the chance I run down and talk to him and, hey this is new with what I'm doing, this is what I want to be doing, and he'll give me feedback and tell me what he thinks I should be doing. He's a good professor to work for, I would have to say.

Another student largely worked alone at night because it fit her schedule better, and was comfortable in doing this. She felt free to call the graduate student who was guiding her if she had questions.

> R: At first I was asking a lot of questions, and I had no idea what was going on, but now that I do and I have notes and stuff, I'm basically on my own. I come in - usually late at night is when I'm available, so nobody's usually around nowadays when I go into the labs. It's basically my own time.
>
> I: Pretty independent?
>
> R: Yeah, it's very independent. Like I said, there's always somebody there to call if I need to call. [The graduate student] is pretty good with that.

One student was not comfortable with the large amount of independence she experienced in the lab and felt her lab work was uncoordinated. She reported that she felt a sense of disorganization and a lack of direction and felt she was working "randomly." Though she had weekly meetings with the lab technician, she felt that she didn't understand what she was supposed to be doing and didn't receive enough explanation.

> Yeah it's still like not that clear and it's been pretty unclear. I kind of wished we did that more than just on Wednesday. I kind of wished, you know, we could like - instead of having it so random like he mentions that we're gonna be doing something within the next week and then I just go into the lab randomly and like look for it and hopefully someone can tell me what that was in more detail so I can do.

3. A few students who were working on technically difficult projects reported that they needed close guidance from lab personnel. A few students who were working on molecular biology projects were closely guided by the graduate student, technician or post-doctoral fellow they were working with, sometimes working side-by-side for large periods of time. These students seemed to suggest that they needed this amount of guidance in their projects. One student described her close supervision, saying that she is dependent on a post-doctoral fellow for both knowing what to do and understanding it.

> I'm pretty dependent on her to know what the next step is, and then she'll guide me, she'll tell me what process we'll have to do, and most of them, most of the processes we're working on, like the enzyme digestion, I know how to do by now, and so she'll just kind of say, "Okay, this is your little formula," and I'll just go and do it. And she is usually right around watching me to make sure, or, you know, working very closely in the room

> so if I have any questions or whatever, I can ask her. So I guess I'm pretty dependent on her for knowing what I'm doing and understanding it. But as far as doing the techniques themselves, I can be pretty independent now.

D. Students who were guided for much of the project by someone other than the faculty mentor expressed satisfaction with the guidance they received.

Students reported that their mentors spent a fair amount of time with them at the beginning of the project, helping them to get the project off the ground. After this initial period, mentors did not spend as much time with the students and about half of the students worked primarily under the guidance of a graduate student, technician or post-doctoral fellow.

> Because basically [the technician] was the one who was always there if we needed help or something. I mean, both of them are so knowledgeable and knew how to teach it that it didn't matter. It was getting done well.

Almost all of the students who primarily worked with someone other than the faculty mentor expressed satisfaction with the guidance they received. Two students said that the graduate students they were working with knew more than the mentor about the laboratory techniques because the projects were part of the graduate students' research specialty. Another student relied on her mentor's graduate student for realistic guidance in her project.

> [The faculty mentor] is, when it comes to that, he really doesn't keep that in mind cause he just wants, "Oh, this would be great to do!" you know, and he's just giving me all this stuff, and I'm like, "Yeah, yeah!" But then I talked to my mentor [the graduate student], and he's like, "Did you realize that if you do this and this you will have 360 samples to analyze, collect data from?" He's like, it's not possible. So [the graduate student] was more of, like, this is reality.

E. Many students established a relationship with their mentors which was different from the customary classroom interactions they had experienced.

1. Students appreciated being able to interact with faculty outside of the usual classroom situation. Because they could observe their mentors outside of the classroom setting, students could see how busy faculty are, and a few expressed appreciation for the time mentors devoted to them.

> Yeah, because he really took time. Cause a lot of times it's hard to get time with faculty, because they're so busy, and I know he was busy, but he would always sit down for an hour and a half, two hours at a time, and just talk to me about the project. And since I had him in a class, he would talk to me before class, and say, "Oh, I was thinking about this..." And so I thought that was interesting, too, that he would take the time out to do that.

One student described her mentor as caring about her team's overall experience in his laboratory.

> I mean he is really there for us, you know whenever we have questions he's like, "You can come in any time." ... He really seems to be concerned with us getting a positive experience from this and learning from this and not just focusing on our small project. He's like, "I want you to see the big scope, the big picture of what's going on."

2. A few students found the research project to be a unique opportunity to establish a one-on-one relationship with faculty for the first time in their university experience. One student appreciated the "working relationship" with his mentor that differed from his previous experience with professors.

> It wasn't the normal student-professor relationship. It was more of a working relationship, which seemed to me more of a real world-type situation.

Another student found a new sense of independence because of being treated as a colleague by her mentor.

> R: Well, my professor and I get along really well, and she's a very good leader. You know, she doesn't give me answers, and she talks to me as if I know just as much as she does about this project.
>
> I: Which is scary sometimes!
>
> R: Right. Definitely. And asks me for my input, asks me questions she doesn't necessarily know the answer to, to see if I have anything different that she hasn't thought of yet. And that helps a lot, it gives me more responsibility....I have a lot of independence with this project, which I've never had with a project, I've never done anything like this before.

The student and her mentor, a female faculty member, discussed other topics besides research, and developed a personal relationship.

> R: We talked about everything. We talked about my life, and my parents, and we talked about lots of stuff.
>
> I: She must be easy to talk to.
>
> R: Yeah.

3. A few students found that their mentor took on the role of an advisor with respect to their education and careers, and wanted the student to continue working with them.

> I mean, he's taken a real interest in me. . . I asked him if I could do a project with him this summer, if I could get a grant, and he's like, "Well, yeah, but I want to get you out in the

> field." So he's seems really interested in what I'm going to do, too, so that's kind of neat that I've built a relationship with him, because my advisor is always off, so I don't see him that much, but it's nice to get to know faculty, because it can be kind of hard.

F. Students expressed mixed feelings as to whether they felt like part of the lab they were working in.

Students were asked to discuss whether they "fit into the lab" or "felt like part of the lab," and to explain why they felt the way they did. They provided a variety of answers and explanations for their feelings. (It should be noted that all students thought their research experience was more valuable than traditional classroom labs, regardless of whether they felt a part of the lab.)

1. A few students reported that their mentors made an effort to make them feel comfortable working in the lab. One student in a team said that her mentor tried to make sure the students were comfortable socially as well as with their project.

> He was always available for us, and even if he wasn't there, there was people that worked more directly with us than he did, but yet he still made himself accessible. He really helped to make you feel like part of the lab, I think, which was nice. It encouraged other people to be nice to us.

A student in a different team said that his mentor set aside a space and invited them to use it any time.

> And he set aside their lunchroom, or whatever, where their refrigerator - you know, there's like three desks or four desks in there. He's said, "Anytime you guys want to come in, you guys need to study, you've got to go someplace quiet, come in here. This room's open to you guys whenever you want to use it. If you need to use the computer for writing a paper, if there's anybody e-mailing or playing a game in it, kick them off, use it."

2. Many students indicated that they felt like they were part of the lab, and related this to feeling comfortable with other people working in the lab. Students who said they felt part of the lab explained that they felt this way because of their relations with the other people working in the lab. One student thought that the lab personnel were friendly and welcoming.

> I think everyone was really friendly and wanted you to feel like part of the lab. We were always invited to go sit in on their meetings when they were discussing things that didn't really pertain to us.

The student quoted above interacted regularly with several people in her lab who were not involved in her project, observing their research. Other students were openly enthusiastic about being in their labs. One student spent time there helping others outside of his project.

> I mean, sometimes I'll just go in the lab, and I know there won't be oocytes ready, or whatever, and I'll just sit around and be like, "Well, is there anything you guys want me to do? Do you need any solutions made, do you need...," you know, I don't go in just to go in do to things, because I feel comfortable in the lab, and I feel like I can be useful there I guess.

Another student explained that he "developed rather strong friendships" and spent extra time in his lab because he liked the people and could learn from them.

> I spend a lot of time there just because I really like the people there and any time I'm in there is valuable, if I can look over someone's shoulder or someone has something they want to talk to me about.

3. A few students felt ambivalent as to whether they fit in or felt comfortable in their labs. These students focused their discussion on the nature of their interactions with others - or the lack thereof. One student described the others in his lab as "working by themselves and doing their own thing." Another student said that the level of difficulty of his project and his lack of experience prevented him from truly feeling like part of the lab, though this feeling had lessened by the end of the semester.

> At the time, I definitely didn't feel like part of the lab, like I really didn't know much. I guess I felt more personable to people when I left, and I was definitely getting along with everyone, and we were joking around, and I was definitely part of the gang. But I mean, I don't have any of the skills or lab background to be part of - like I couldn't be doing my own project along next to them, 'cause I really don't have the skills yet, and that's because I'm an undergrad, and haven't spent three or four years in the lab setting. But other than that, I felt pretty good.

Another student was ambivalent about feeling like part of the lab, attributing this to her shy nature rather than the actions of others in the lab.

> I: So do you feel part of the laboratory?
>
> R: Yes and no. I mean because I'm kind of - in a way I'm kind of shy so I kind of don't like to go ask questions. If [my teammates] aren't there I just kind of stay to myself, do my research and don't interact too much. But if they come and ask me how things are going, you know, I'll chat.

4. A few students did not feel they fit into their labs. Two of these students had expectations about working closely with others and found themselves not as involved as they hoped they would be. One of these students thought that he and his teammate would be involved in a team effort with the lab, helping out the graduate students and professors. Instead they did their own project, which he viewed as not being connected to the lab's team effort.

> I kind of expected more so to be involved with the professor. I'm not that involved, which is not a big deal really, but it would be nice to be involved. I also kind of expected to be more on like a team type thing, like me and my partner would just do little things perhaps helping out the whole team effort, like the whole group of scientists or whatever, all the graduate students and professor are working towards one thing and me and my partner are helping along the way in whatever ways we can, doing little things. I thought that was kind of what is was gonna be like and it's really not. It's like me and my partner are just there doing our thing, not going towards anything. Well, not that it's not going towards anything, but it's not going towards a team effort.

The other student also expected to be working more closely with her mentor and others in the lab and pictured the lab as a busy place with people working together. Instead, she found herself working in isolation much of the time.

> Well, I thought I'd be working with [the mentor] more and I thought that there would be more intercommunications between other people and me in the lab. I didn't realize that a lot of times there's just not anyone in there. I always, I kind of I guess pictured it, this place where there's always people doing stuff all the time.

This student also felt isolated because she was unable to understand the laboratory conversations.

> Yeah, I know he's there but he's just been working on grants, getting some stuff. Or else talking with like the graduate students about things that I completely don't understand. There's a lot of time just this constant dialogues that are going on, that sound like they're in a foreign language to me.

Two students on a team reported that even though their mentor was friendly and inviting, they didn't really feel like part of the lab simply because they were working in an isolated room away from the rest of the lab.

> We weren't part of the lab, just cause we had to work in the quarantine facility, which is down in the basement, separate....Like, I don't know anyone's names other than [the graduate student] and [the mentor].

5. *Almost all students were invited to their mentors' research group meeting, but their attendance was sparse.* Two students went to one meeting, but most students couldn't attend because of schedule conflicts or decided not to do so.

III. Team Work

A. Drawing on their previous experiences, students expressed varying opinions about the advantages and disadvantages of working in teams.

In interviews before the start of their research projects, students expressed mixed feelings about their previous experiences with working in teams. Because of their prior experience, they were realistic in discussing the prospect of working in a team.

1. A few students said that working in a team would be a good experience because they thought that scientists conduct research in teams. A few students described science as being conducted in teams, and thought that their research experience would be more realistic if they were part of a team.

> At least they tell us that the vast majority of projects or research work that's done in biology or chemistry is not done by a lone researcher, by himself. You know, there's a group, there's a lab, a team of people that are working for a common goal.
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> ****************************
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> But I think it's valuable to be working in groups because, say, I'm going to go into research. You're not going to be working all by yourself, you're going to have to work with other people and have their input.

2. Students reported having negative experiences working in teams. Students discussed various problems they encountered with group work in classroom settings. One student found that some team members simply don't contribute - a common complaint among the students.

> I: So what was the problem?
>
> R: I guess it's just when a couple of individuals have to do all the work and the other guys just slack off.

Another student saw a different side to this. He originally wanted to work individually because he felt that he tended to let others do the work, and he would learn more if he was solely responsible for the project.

> I: Would you prefer to work alone, or in a group?
>
> R: Probably alone. I think I'd learn more working by myself, doing it all by myself, than working in a group.
>
> I: And why do you think that is?
>
> R: Just because I'm doing it all, there's no excuse for me not to know it...When you work in groups you tend to say, "Oh well, you can let the other people do it." And you might not have to worry about it.

One student felt that it takes time for team members to learn to work together. Because of this, he thought that working in teams for short projects during conventional labs was inefficient.

> I think it was unreasonable to expect students that didn't know each other previously to come together in a group of three or four, meet, depending on the length of the lab, two or three times, be able to interact in the most efficient way possible for your desired outcome. A lot of the time that you could have used for more practical experience I think was just spent trying to figure out what your lab partners were like.

3. Students thought that working in teams had several advantages. A few students indicated that they were not confident enough to do a research project on their own, with one remarking, "I didn't think I was ready to be alone in a lab." These students expressed a need for security, and thought that working with others would make for a more successful and less stressful experience.

> This is my first independent project, and I'll probably do more if this really does well, and as a first one I think it's be easier to go in with somebody else, as far as getting into something like that with someone else you can always hold each others' hands, so to speak, and not just dive into it by myself. I'm afraid if I would do a project completely by myself all alone, I think that if I got stuck or, if it just didn't go very well for me, that it would give a bad taste in my mouth.

One student pointed out that students have different abilities, and could work more efficiently by combining their skills.

> And you get to know the people in your group, you know what each person's weaknesses and strong points are, and you can utilize or use that to the advantage of the group and you can do things more efficiently. You don't waste as much time.

Many students said that they could share their knowledge and help each other understand what they were to do in lab.

> If you have questions your group is right there and if you don't understand the lab you can get their insight into what they think it means. Some of the directions sometimes seem ambiguous and I'm, well, should I do this or am I supposed to do the? They'll tell me what they think, and then I'll tell them what I think, and then we'll decide what we thought it meant.

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> You don't always know the answers to every question that comes about, and this way it's kind of like a brainstorming thing. You all can bring your knowledge together, and if there's something I didn't understand, they can explain it for me or vice versa.

B. The process of forming the teams.

A total of five teams were formed: two teams of three students, and three teams of two students. Two students who had originally requested an individual project found themselves working in teams.

1. Most students chose a mentor based on a research area they were interested in and found themselves working individually or in teams, depending on whether the mentor they chose had agreed to have a team. The following student found herself on a team after indicating an interest in the mentor's research.

> When I went in for my meeting, I had a few professors picked out and then [the course coordinator] showed me [the mentor's] experiments and I said, "Oh that sounds..." I put that on my list of preferences too.

One student explicitly chose to work on a team because he thought it would provide the support he would need in doing research for the first time.

> I think it'd be easier to go in with somebody else. As far as getting into something like that with someone else, you can always hold each others' hands, so to speak, and not just dive into it by myself. I'm afraid if I would do a project completely by myself, all alone, I think that if I got stuck or if it just didn't go very well for me, that it would give me a bad taste in my mouth.

2. Except for a pair of students, the students had not met each other before finding themselves starting on the project together. A few students thought it was important for them to be able to choose their fellow team members and did not like being placed together in an arbitrary fashion. One student thought this led to an awkward situation because of individual personalities.

> [One teammate] is really quiet and doesn't really get involved much - it seems like when I go in, I seem to talk to [other teammate] more. I don't know, it's just, it's strange because it's like we're all just thrown together, and we hadn't met each other.

The two students who had requested a project together found that a third person had been added to their team, and one expressed an objection to this.

> And then we found out that there's actually gonna be three of us. I guess that, given the choice I probably would have worked in just the group of two. . . The whole idea of working with a group is that you know who you're gonna be working with.

3. The logistics of finding a mentor delayed the formation of three teams. The three two-person teams each had one member who started a week or more after the first team member had begun.

C. Teams exhibited varying styles of working together.

Teams showed variations in their working styles, from working together on every aspect of their project to cooperating by keeping each other informed and exchanging information.

1. One team of three worked closely together on a single project involving a gypsy moth parasitic wasp, planning and sharing the work among themselves.

> We would all be there at the same time when it came to setting up the experiment. Towards the end of the semester we got together again. Well actually through the semester for the various rewrites we would always agree upon a time to meet at the library because there were various drafts to the proposal. Towards the end of the semester we had to include our conclusion and data. When it came to be the end of the semester where we were just collecting the data. . . I think all three of us at various times went in on our own when we had a couple of hours, because that just involved the busy work of counting the wasps and determining sex. . . Anything having to do with the actual paper that was due, we got together and maybe divvied it up, but then we got together and reviewed it. And then setting up the experiment we all did together, and then actually collecting the data, that was done a little bit more individually, I guess.

The team wrote a joint proposal, going through a process of making decisions about what they would do in the project, dividing the writing task among the themselves, and then combining their work into a final product.

> Well, initially when the semester began we had to turn in a proposal rough draft which included our introduction, materials and methods, so we essentially just decided on a time to meet. We met, you know, in a library on campus . . . discussed what we had, discussed further what we had started discussing with [the mentor]. And one of the suggestions he gave us for the experiment sounded like something we understood, could pursue, and then we basically brainstormed for the majority of the content of the paper. Then I think we actually broke down, I think I worked on the materials and methods, and [teammate] and [teammate] each took part of the introduction, to actually draft the paper. Then we got together again, to read through each other's parts to make sure that there weren't any rough transitions, and then we just typed it up.

2. The other team of three students exhibited a different type of cooperation, formulating hypotheses and planning their work together but working in the lab separately. Like the first team, this team also made joint decisions in setting up their project by meeting with their mentor and formulating hypotheses.

> And we went in for the first meeting with him, and he sort of let us - he didn't tell us what we were going to do, but he asked us - okay, he's like, okay, you want to know this, what would you do? We talked through it, and we came up with like three hypotheses, and then it was just a matter of running experiments to test them. It was, you know, he helped

> us, but he didn't feed it to us, which was good. I mean, he made us work for it. He made us actually sit down and actually think about it and comprehend how we could possibly run the experiments to try and prove what we were trying to prove.

The students wrote individual proposals after the initial meetings with their mentor, and did not read each others' drafts. They performed their experiments in parallel, rather than together, because of their class schedules.

> We were working on separate things, it was the same things we were trying to answer, but we were doing it separately.

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> The thing is, we're supposed to sort of be working as a team, but we don't all have the same free time. See, like Mondays I've got class till 3:30, and then we have our group meeting...I came in on Tuesdays and Thursdays cause I only had class until 11:00, and I would stay until whenever I had the experiments done, and neither of them had Tuesdays and Thursdays open. [One teammate] usually came in on Fridays, [other teammate] came in on Mondays, sometimes Wednesdays, so we were never - we never ran the experiments at the same time ever. We were never actually doing the experiment in the lab at the same time.

The main interaction among the members of the team came during their weekly meeting with the mentor, in which they were expected to take the lead in discussing their work and planning their next steps in the project.

3. The other three teams' working styles were variations of the those exhibited by the first two teams. One team wrote a joint proposal and the members worked in the lab together to a large extent. Members of the other two teams cooperated in writing separate proposals, with one team working in the lab together and the other working on parallel projects. The members of the latter team worked largely independently of each other, sharing information but seldom being in the lab together because of their schedules.

4. Students who did not often work simultaneously in the lab exhibited several ways of linking together as a team. Students who did not work together in the lab at the same time would nevertheless hold discussions which helped each other in their projects. They reported that seeing each others' experimental results and asking each other questions were helpful.

> If you've got their experiments too, you've got a lot more to judge what you're doing, how you're doing it, and how things are going. So you've got a better understanding of everything.

Two students described themselves as working largely independently of each other, but they aided each other through sharing ideas and discussing their progress.

> We shared ideas, like if I found something new, or if we found something new, we would share that, or tell each other and look at it and discuss it. Like basically she found most

> of the occurrences where the stigmata was overlapping the crystals. And it got my attention and I looked for that too. And then after we looked for it we talked about it too.
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> ********************************
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> The leaves came from the same plant. They're all cloned, they're pretty much the same leaf. But we both worked with several leaves, and we dissected the leaves ourselves, and if I found something that was extremely unusual, I'd give it to him to look at, and maybe he'd take a few pictures of it.

In several instances, a student learned a technique and taught it to another student in the team.

> If we learn something before someone else, it's our job to kind of teach it to the next one.
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> ***************************
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> At the beginning, we all went in and scheduled times to learn the procedures and stuff, and then it got to the point where I would come in, [the mentor] would show me, and then I would have to come in and show them individually how to do that.

Two of the teams kept a joint lab notebook. One student described their notebook as allowing team members to keep abreast of what the other members were doing.

> Basically at the beginning they set up a notebook where we each had about the third of it. Whenever we were in the lab and we did something, we'd write down what we did. Then if another person was in the lab and they had any questions about exactly what they were supposed to do, they could look back to another person's area what they did. Yeah, that continued. We kept track of what we did in the lab. ......Yeah, because, you know, even near the end when you'd go in and you were thinking about doing a gel, or whatever, you could look, and like, "Oh, okay, [the teammates] just did a gel yesterday."

D. All students saw some benefits of working in a team.

1. A few students felt that being in a team helped them deal with their apprehension about being in a research lab for the first time.

> The advantages were just the fact that going into an unknown situation . . . it's a little more comfortable, we can share the apprehension among a couple of your peers.

2. Students appreciated simply having a companion in the lab, a peer they felt comfortable talking with.

> It's easier to work in the lab with him. It gives you something to talk about, and someone to talk with, and still do your work.

One student had commented on being intimidated by the knowledge and experience of the other people in the lab, and appreciated having another inexperienced person to work with.

> We get along really well, it worked out. I like it because, you kind of have another resource and this person's kind of at your level compared to all these other people [Laughter] that know a heck of a lot more than me. So, I think it's kind of a comfort thing, too, just having somebody at your own level there.

Another student described herself as shy - "I just kind of stay to myself" - and did not talk to other people in the lab besides her team members.

3. Students thought that being able to discuss their work and make decisions with the other team members made decision-making easier, and lessened their dependence on their mentor. A few students said that working with other student allowed them to function more independently of their mentors.

> You can always - I mean, if you have a question you don't have to go to the professor, or you don't have to go to the lab tech. You can go to one of the other people and ask them if they know, and it's more of a partnership to work upon each other's knowledge.

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> And then when we were actually deciding on the specifics of the experiment, I think it went a lot smoother being able to bounce it off of other people. It allowed us to decide on some things on our own, whereas I think if any one of us were working individually, we would have relied a lot more heavily on going to the professor or to [the graduate student]. Just, you know, things you thought you should do a certain way but you weren't quite sure so you wanted to have a second opinion, where you had two other people that could--that you could discuss it with. For the most part we were able to decide the majority of the little minor details. Whereas, if you're working by yourself on a subject area that you hadn't had any experience in, chances are you would have gone to your mentor a lot more.

The two students who had originally requested individual work thought that they had a better experience than if they had worked individually.

> I didn't know how it would be at first, but it turns out to be more helpful. Like if I didn't catch one of the points the professor pointed out, my partner will know and she would guide me there. As the lab started, at the beginning of the lab, she already started a week before me, so she already knew more.

4. A few students thought that they and their team members had complementary knowledge and abilities and benefitted by being able to share these with each other.

> And he has a better chemistry knowledge than I do, you know. So we kind of help each other.

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> Like a lot of the stuff I didn't know, he could tell me, he's smarter than I in science, he's just far ahead. And so he can benefit me a lot in that aspect. He's from Hong Kong so I can benefit him a lot, like communication wise, writing the papers and stuff. . . I mean, without both of us working together I don't think it would be possible because you come to hurdles and it's just like oh you don't know, and then he'll solve the problem or I'll solve the problem and the other one probably couldn't have solved it on their own. Perhaps could've but it would have been very problematic.

E. A few students saw problematic aspects with working in their teams.

All but one of the students indicated that they were satisfied with their experience of working in their teams. However, a few qualified their expressions of satisfaction with discussions of problematic aspects. These were centered on the personalities and personal interactions among the team members.

1. One female student had a negative team experience. This student did not feel she was able to contribute to the team effort because the two male students in the team did not value her contributions. The two male students, older returning students, had requested to work together, and later found that she had been added to their team. The female student felt the two male students wanted control of the project, and she experienced difficulties at the onset of the project during the proposal writing phase.

> I don't know. I try and put my input into it, but it's kind of hard working with - I don't know if I'm just reading into this more, but I'm working with two guys who, sometimes it seems like, they want to take control, and I want to get in there too. I don't know. I tried to put my input into the writing and stuff. And then [teammate] takes it home and types it up and so he kind of has the final say on words he chooses.

Her difficulties in working with the other two students continued until the end of the project, when she found that the others had written the paper without allowing her to contribute..

> Well, they finished the paper without me. OH! I'm so frustrated!...I always get so mad because I offer to help, and they weren't nice. And then they finished the paper without me, they wrote the results and the discussion, they didn't tell me. They'd get together and do it without me, and even if I was there, they wouldn't listen to me. I don't know. Maybe it's a combination of me being a girl, and them being returning students, I think. They probably think that they know more than me.

The male students in the team did not directly discuss the situation, but one hinted at a difficult situation.

> The experiment itself, I think, could have just as easily been done with two people...There hasn't been any real difficulties. I just think, that's my own personal feeling that, it would have run a little smoother.

2. Two students on different teams felt that the responsibility was not shared equally among the team members and thought they had to do more of the work. One of the students felt that he had to take on the task of being the team leader, and the other felt that she worked harder and cared more about getting results than the other members of the team.

3. Three members of one team did not think of their work as a team experience because they were not able to work together in the lab. However, they described a generally positive research experience and were able to discuss the advantages they received from working on the project together. One of the students was frustrated by not being able to work with the other students.

> It would have been beneficial for us to be able to work together and to be able to construct this because three minds are better than one. It just - I mean, we helped each other in the lab once in awhile with the understanding and everything, but it was really more of an individual lab, for me at least.

IV. Students' Views of Their Research Projects

A. Students were motivated to do the research project largely because they wanted to do science rather than mimic the process through simulations.

Students were uniformly dissatisfied with science course labs, describing them as simulations. One student wanted to do something other than "just going through the motions and pretending," as he felt he was doing in the Biology 151 labs. Another student used similar language in describing her feelings about the 151 labs.

> The labs we do now are just constructed. I mean, they're just made up and you know the results and it's just kind of going through the motions.

Students expressed frustration with their 151 labs, feeling that what they were doing was too easy and pre-planned, unlike real science.

> I knew the modular labs weren't science. I knew it wasn't. Things aren't that easy. That isn't why people have problems with sciences. It isn't planned out step by step little procedures. . . It seems like they're too easy, too planned out, too generic, too, you know, whatever. It doesn't seem like it's pulling the whole science issue at you. It's more or less tiptoeing around it.

Many students wanted to do something in which they would actually be making a contribution to science.

> I'm doing it to get something out of it and to be able to make a contribution in a small way. You know, I'm not anticipating any large contribution, but being able to do something I think is a lot more rewarding than just doing a modular lab.

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> I still think that the fact that you're actually doing something with the outcome that can be beneficial to many different people...that was a lot more appealing to me than going through another modular lab.

B. Students uniformly preferred their research experience to science course labs because they felt they were actually doing real science.

1. Students felt that they were actually doing science in carrying out their research project, and contrasted their research experience with the classroom. One student talked about the difference between an experiment in a science course lab and in his research as a contrast between using a common "visual teaching aid" and doing something that hadn't been done before.

> Like if I do an experiment (in a course) it's not to me an experiment, because it's something that, how many thousands of people have already done. It's basically just some sort of visual teaching aid. . . What I did (research), it felt like more of an experiment. It was something that was never done before or maybe only done before by one other person or maybe a group of people. It was something that was new, something that was different. It was something that nobody necessarily knew the answers to, whereas the lab I went to today, I could've just walked in and got the answers from the TA.

Another student compared a science course to research in terms of learning vs. making knowledge.

> One is learning about the knowledge in a course--like organic chemistry, you have a textbook full of everyone else's research. And one is making the knowledge, you know - this is where the textbooks come from, these labs like [the mentor's lab].

Other students believed they were doing science because they were following the process of science in dealing with the unknown.

> Science isn't all planned out, isn't all step by step procedures that labs, whether it's zoology or physics, gives the impression that it is. Science is trial and error and going into things blind not knowing what you were going to come out with, whereas the labs seem to have this other agenda, and you know what's going to happen.

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> I mean, we were doing the scientific theory thing. We'd come up with a hypothesis and work it through with our methods and test it.

A few students believed they were doing science because their work could help solve real problems.

> And I think, you know, if we contributed even a small amount of information that taken with other bits of information might help, you know, delay that problem from occurring, or prevent it, then, I mean that's what people are doing research for.

Other students said that being able to apply the science knowledge they had learned made the experience seem like real science.

> I was also applying like all the things that I've learned, not all the things, a lot of the things I learned in all my science. I applied some of my chemistry, I applied some of my biology, I applied some of my physics

A few students said they had actually found something unexpected, which to them made the experience one of really doing science.

> Basically because we found something that had never been seen before. That surprised our professor, and completely threw off our entire experiment.

2. Students thought that learning in a research project is fundamentally different from learning in a science course. One student described the research experience as "sink or swim" compared to science course labs, explaining that the experience of doing real things in the research lab is a more effective way of learning.

> It kind of is just a sink or swim kind of thing, where they just throw you in and they just let you do it. And I think you learn as far as writing papers, doing research, that kind of stuff, it's something that you just kind of need experience to learn. You learn it a lot faster that way, a lot better that way than if you were to write a phony paper on phony data that they gave you in our lab or some obscure experiment that you did.

A few students remarked how actually doing research makes for deeper and more meaningful understanding when compared to classroom learning.

> I mean these aren't things that you really learn in classes. You learn a little bit, you like hear the words. But I mean I'm getting a real definite view of what these things really mean. . . And actually going in and doing the research yourself rather than somebody just saying, "Well, this is this." And naturally going out and finding it out for yourself, so I think it's a lot different. And you learn more that way. It feels like I learn more because I just went out and found it, read about it, and had to think about it myself and figure out what it meant.

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> It's easy to talk about or easy to discuss in a class, but once you actually get in the lab and have to worry about you know, actually having controls. . . setting things up correctly . . . it sinks in a lot more, I think.

Many students said that they did not get much from science course labs in which they would follow a "cookbook type recipe." One student remarked that she learns better when working in a real situation, "haphazardly" in real time, rather than in an organized fashion as in a course.

> R: But if I'm going to choose a way for something to be difficult, this is the best possible way. Cause that's how I like to learn things, kind of like haphazardly having to know it at

> that moment, you know? That's how I learn things the best, rather than just, "Here's some calculus problems, and here's how do them." You know?
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> I: So explain "haphazard." What do you mean by that?
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> R: Like haphazard as if I'm in a lab, and we're talking about something, something relating to, say, signaling genes or something. I'm like, "What's that?" Like learning about it at that time. That's kind of haphazard, because it's not like going through, "These are what, this is what a gene..."

The student went on to explain that she learns better when what she is learning is in a larger context, which she doesn't find in courses.

> Well, in my chem lab you just, it's kind of like how I said before, you learn stuff when it's told to you. You don't really know why you are doing this lab, but "Just believe me when I tell you this." And you're like, "Okay," and you learn something, but I don't think that I gained as much out of something like that than if I had a bigger goal in mind, and this is part of it. Then it's much more easy for me to learn...

3. Even students who found the research experience extremely difficult thought the experience worth going through. One student who was very positive about his experience did not get the expected results, and described how his project was a "tremendous struggle" for him.

> R: It was probably the biggest thing I struggled with ever before--this experience in the lab--and maybe I didn't see until the end how rewarding it would be, or how much I had really learned. . . It's very easy to get discouraged in the lab, very easy to feel that you have no idea about what you are doing. It was very easy for me to feel that maybe science wasn't my thing some days, because things wouldn't go right, or experiments wouldn't go right,
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> I: I'm almost surprised to hear you say that because you were so positive.
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> R: Right--absolutely. Again, I didn't, I mean I really thought . . . it was a real struggle in the lab. It wasn't, it wasn't cakey and wonderful the whole time. Even though I did love being there, it was a tremendous struggle.

The student quoted above said that there was "no substitute" for doing real research, citing the need for his "imagination to be nourished".

> On an intellectual level--in terms of thinking about this work, what it means, where it's going, how do you solve these problems, why are we interested in these things. It's fascination; these are hard things to describe, but you know it's just . . . it's human nature to be fascinated by things I think . . . some people are drawn to them more than others are, and I need my imagination to be nourished, I need my fascination to be nourished. If it's not, I get jittery and uncontented. So that's what was so drawing about the lab.

C. Students universally thought that their work was meaningful and important.

All students thought their work was of some scientific importance. They did not view their project simply as an educational exercise similar to a science course lab.

1. Most students saw their projects' importance and meaning in relation to their mentors' research work. It was meaningful to the students because it was meaningful to their mentor and was within the context of the mentor's lab.

> And it just gave me a good feeling, because I mean, this is a big, new database for him, so he'd like to get all information out of it, so I feel like I was helpful in giving him information. . . Yeah, because it's just getting off the ground, because it was just last summer that he got all of this information...
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> I just went to a seminar the other day ...and afterwards the professors were asking him questions, and they actually asked questions that I was working on that he didn't have answers to. So he said, well, let me get back to you - I have this student that's working for me right now, and we'll find out soon enough. So now I think, well, maybe this is sort of important, even though it's pretty simple.
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> I think it's really important to the professor since she's done a lot of research on stamatos, and this is something that she can build on.

A few students noted that their work would be continued by others in the lab.

> [The mentor] had said that the next people that come in, he's going to start them where we left off and carry it on through that.
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> So now a couple of the doctoral students over there are doing more work.

2. Students thought that even if their original hypotheses were disproved, the results were still meaningful and they believed they had accomplished something. Students reported various results, ranging from being able to largely finish what they had proposed, to disproving their original hypotheses. Many students had results that disproved their original hypotheses and prevented them from carrying out their proposed research according to their initial plan.

> R: Basically what we were looking for was an up regulation in the serotonin in the spinal tissue in rats.
>
> I: Yeah, I remember you were doing that.
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> R: Basically we thought there was going to be enough regulation and as it turns out there wasn't.

One team of students disproved two hypotheses and ran out of time before coming to a definite conclusion.

> Two of the hypotheses were able to be tested by using a transcription blocker, and we ruled those two hypotheses out. Then at the end we were testing to see whether we could find the protein that was being triggered and single it out, and we never finished that part of it.

Nevertheless, students felt that they had advanced research in their area.

> I mean, it's disappointing when you don't get what you expect, but I still think it's really significant results, because it can be used as a stepping stone, and the groundwork to do her project, you know? And, it gives a whole new lead that we weren't expecting to be there.

3. Students found their work satisfying because they felt it was advancing science in some small way. They were realistic in their assessments of what they had done, and did not exaggerate its importance.

> I mean I'm not saying it'll be significant but it might be worth consideration by other people and they'd be like, oh, that's kind of interesting. It might lead other scientists to continue the work, so I have a feeling that like my semester's work will maybe go towards something at least minorly important. Not important, but it might help something out, you know, so I think that's the whole idea behind science.

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> I realized that in the grand scheme of things it was just one little grain of sand on the beach, but, you know, you get enough people doing a little bit of stuff, and it adds up.

A few commented on how their projects fit into broader scientific concerns.

> R: But what's most exciting about this stuff is that these processes we're looking at seem to be evolutionarily conserved. So the molecules we're looking at have been found in worms and in humans and in everything in between.
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> I: They're universal.
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> R: Absolutely, yeah. So that's what makes it important and exciting work.

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> Yeah it's really useful in the big picture too because there's so much relation between like human genes and fly genes. They've found all these homologies for the same, like really near the same proteins that do like similar functions in humans.

4. Many students commented on how they felt their work was relevant to practical concerns, and several felt that it had implications for human health.

> Well, defoliation's a huge problem. I mean, we saw statistics on the population up Northeast, and it's just incredible. So yeah, obviously it is worthwhile.
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> It could be very important eventually. Depending on what we find out, it could really vary in how cancer eventually may be treated, because we'll know more about the whole process behind it.
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> Well, fertilization is something that occurs in every species. And somehow maybe fertilization of the xenopus frogs could be related to human fertilization. I mean if there is a protein involved in xenepus fertilization or whatever - I mean it could be used for human needs. Like if there is a defect and there is a disease which inhibits fertilization, where they have problems with fertilization.

D. Students described their projects in terms of being tangible or being abstract, and generally found tangible projects easier to understand.

Students were able to compare each other's projects in their Biology 152 lab meetings, and could see the range of the types of projects they were doing.

1. Most students had projects dealing with visible organisms, and generally thought that the theory behind their project was easy to understand and the techniques easy to master. One student working with a gypsy moth parasitic wasp felt that her project was technically easy and did not involve understanding complex theory.

> It was a pretty easy lab. It was pretty much just busy work, just counting, but they needed to be done, and it didn't really take too much theory.

Another student also thought her project was easy to understand, and compared it to other students' projects in molecular biology.

> I don't think the ideas are very difficult, or it doesn't take very long to learn about it. Basically you can learn the basics about it from talking to the professor maybe twice. Whereas other people, I know they were still learning how to the things throughout the semester, because they were such complicated ideas, and you had to have a lot of chemistry background. With this you saw the stomata, you saw the crystals, saw the vascular bundles, you know, that's all you really had to do was see them, and see where they were in relationship to each other, and be able to analyze that. Whereas, I don't necessarily like just doing tests on things. OK, that turned blue, so that means. . . you know, whatever.

2. A few students with molecular biology projects thought the theory was difficult to understand. Though not all students with this type of project commented on this, a few felt that the theory behind their projects was complex. They indicated that they had an incomplete understanding of what they were doing.

> It seemed that when I talked to people, it was, "Oh, yeah, I spent one hour on a computer program that was set up for me." And I'm like, "Oh, yeah, that's cool. I spent the last five hours reading out of a textbook that I'm not getting any credit for to try to understand it, so I can go back and not look stupid."
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> The part that was difficult was getting an understanding for it and grasping exactly why you were doing what you were doing.

One student expressed his growing frustration with the "intangible" nature of his molecular biology project.

> Well it's like, it gets to a point where it's like, I mix these things and it's just so intangible, stuff is just so minute and stuff is going on in these little test tubes and you can't even see it. It's just not something I want to do...I just don't want to do that, I know that, it's just not that tangible. I mean not that I, I'm not saying I hated it but I discovered I'd rather do something else than sit around and mix liquids in test tubes. [Laughter]

Another student decided against doing a molecular biology project because he thought it too advanced for his first research experience. He investigated medically-oriented projects, but chose to do an ecologically-oriented project because he perceived the medical projects were "over my head."

> But they seemed very - still too in-depth for me, a little over my head at this point....I wouldn't feel as though I was contributing as much.

3. Students with molecular biology projects generally described their project as being an incremental part of a larger project. In contrast, students working with visible organisms described formulating and testing hypotheses to answer a question. One student with a molecular biology project summed up her project as completing a step in a longer process that would take more time than a semester allows.

> There's an area called the coding region determinant, which is in the coding region, acts as a destabilizing element, and so what we were trying to do is kind of determine translation, how that affects it, just how it acts as a destabilizing element. . . Basically as far as I got was just creating some different DNA that would be used as templates to move it around. Basically it's been moved to different places, but it hasn't - we didn't put it into bacteria to see what happens.

E. Students thought the experience of writing the proposal and the final paper was valuable.

In the process of getting started in the lab, students wrote proposals that described their proposed research. The proposals were reviewed by their 152 teaching assistant, another 152 student, and the course coordinator.

1. Students spent large amounts of time reading the research literature and writing several drafts of the proposal, and most of them thought the process was difficult. A common complaint was they did not know enough about what their research would entail to be able to write the proposal early in the project.

> It was kind of tough for me because I don't know that much about it, and so [the post-doc] had to basically tell me what we were going to do, because I had no idea. And so, the introduction was interesting for me to write, because I had read many articles about the subject, so I wrote that pretty easily on my own. And then, the method was the part I kind of got frustrated on because I had to say, "______, what are we doing?" And she basically had to make me an outline, and I tried to fill in.

A few students had difficulty writing the proposal because the course of their research would depend on work that they had not completed at the time of writing the proposal.

> For our experiment, we had the first set of hypotheses that were done and everything, but we hadn't really discussed the second ones or what we were going to do for testing after we had solidified or rejected the other hypotheses. Mine was a really - it was really hard and incomplete to write.

Because of the changing nature of their project, a few students handed in incomplete proposals or delayed handing them in until later in the semester.

> I was literally months behind in the deadlines that were set by the 152 people...Because of the nature of my project I couldn't write about it until I absolutely had to.

2. Students received varying degrees of assistance from mentors in writing the proposal. Mentors at the very least read and commented on a proposal draft before the students gave it to the Biology 152 teaching assistant, and a few mentors worked more extensively with students.

> I came to him with like the hypothesis and he talked to me how I could revise it, so on and so on. Basically it got to a point where he would read over it and be like, "Yeah that's pretty much exactly what I would put."

In general the mentors made relatively few comments on the students' draft, leading students to believe that the proposal was at least sufficient. Many students were surprised to get their proposals back from the course coordinator with numerous corrections and suggestions for revision, even to the extent of "the hypothesis is not acceptable."

3. Though students found writing the several drafts of the proposal difficult, they almost universally expressed approval of the task.

> The proposal was worth doing, as much as I regret having to have done that. It was definitely beneficial, and as much as I hated doing it, it really paid off - I mean, as far as the rest of the paper went. It was really a good move.

A few spoke of the value of having to write and rewrite until their ideas were expressed clearly.

> I find it very difficult just to clearly state what I'm doing when I'm talking, much less have to write it down. . . And, I think that having to do the proposal and having to rewrite the proposal with comments from my TA and from [course coordinator] was a good idea.

Students said that doing the proposal made them find and read the relevant research literature that they might not have read otherwise.

> R: I think it's necessary to do it. . . Because if I hadn't researched what I had to, had to research the topic in the library or do journals or whatever, if they hadn't had that part required, then I probably wouldn't have, and wouldn't have gotten as much out of the lab.
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> I: So you probably wouldn't have read as much?
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> R: No. If you don't have to, you know, you don't do it.

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> In trying to write the introduction, I really had to make sure I knew what I was talking about, so I had to read the articles about the information, and so it was a really good way of making me do the reading.

4. Students had mixed views on the value of the peer reviews. A few students were helped by having other students comment on what they wrote.

> But having somebody else that doesn't know anything about the topic, you know, it helps you write more clearly for them I think. So that helped.

But most did not think that having other students read their proposals assisted them. A common observation was that "people just don't understand what you're talking about": the students did not know enough about each others' research area to offer constructive comments. However, many thought that reading other proposals was helpful to them.

> I mean mostly what was helpful was not the reviews, it was you reviewing them. I got to read others, I got more from that than from what they told me.

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> Since I was having difficulty writing up my own, it was good to look at what other people were doing, too.

5. Though students saw the value of writing a final paper, they had mixed feelings about the poster session. Students thought of the paper as the culmination of their proposal drafts, which they judged to be a valuable exercise. They were split as far as how they felt about the poster session. Several students were enthusiastic about it, expressing pride and thinking the session important and enjoyable.

> I thought that was great--I really enjoyed the poster session a lot. It was very important to go up and spiel to people about your work in front of people.
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> I liked seeing what everyone else did. And, I liked, I mean. . . I liked answering questions about it and stuff. It was pretty informal, so it was nice just to walk around and see everyone else's.

One student's poster is on display in the building where she did her research.

> And I'm really proud of that. I bring my friends through there, "Look what I've done!" There's a little light you can flick on to look at it.

Other students were ambivalent or negative about having to prepare a poster and present it at the poster session, their most common complaint being a lack of interested viewers.

V. What Did Students Gain from their Experience?

Some of the benefits that students gained from working on their research projects, such as being able to establish a one-on-one relationship with a faculty member, have been discussed earlier in this report. This section reports the students' perceptions of other benefits they received.

A. Students gained an understanding of how scientific research is actually conducted and a glimpse of the varieties of research on campus.

1. Students gained an understanding of the scope of research on campus and the different possibilities available to them in research, both now and in the future. Students indicated that they did not know much about the variety and extent of research on campus. For a few students, simply looking for a mentor was an education in itself.

> You don't realize like how many things go on at this university and all the research that goes on and all that stuff is on the cutting edge.

Another student remarked that she appreciated being part of "something so big" and having the opportunity to take advantage of what the university had to offer.

2. Students received their first glimpse of scientific research in real settings. Students spoke of the importance of seeing and experiencing actual research for the first time. One student remarked that he "never really knew what science was, totally," and spoke of his experience as an introduction to the scientific community.

> This was my introduction to the scientific community; to see how it works, to see where knowledge comes from, how it's gained--that's what I learned, that was the most important thing to come out of this.

Many students talked about the importance of being in a real research lab in a holistic sense, not simply in terms of their own project.

> I would say what I got out of the experience is to see how an actual lab is run, and just to say "Oh, I'm going to go and do research" and to put an actual feeling of events and time, and different things to get like a picture in your head. To say it is one thing, but to actually have done it.
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> I'm actually doing something in the real world, and I'm actually out there. I'm actually like, you know, this is what researchers do. I'm working in a group, I'm getting to work with people and getting to know people and getting research techniques down and learning what it's actually like to actually be doing this.

As seen in Section IV, many students were seeking a genuine research experience, and felt they experienced one.

> I got to see how actual labs work, a lab in the real world, and not just a classroom lab where the research is done by students in a classroom setting. This lab is actually used to do real research.

3. Students experienced the day-to-day reality of working in a research lab, and the responsibility and commitment of doing research.

> I sort of see how things are run, when you're in a real lab setting, as far as, you know, the precautions you take, and, um, keeping things sterile, and how you have to keep the conditions same from one trial to another. . . Just, it seems like it's, you have to be a bit more responsible than just showing up in a classroom in the Zoology Building.

By actually working in research labs, students found that the hours could be long and the work tedious. One team of students had a project which called for a large amount of repetitive work.

> We'd be in there for four hours, and you'd just be like, "Oh my god!" You'd go push yourself away from the microscope, and you're just frustrated and everything. You've got to stand up, and whatever, go walk around, stuff like that. . . It did get pretty tedious. It was like, "Man, I don't really want to go there tomorrow. Do you?"
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> Each one had between 100 to 500 of these inside it. Yeah, so that's why it was so long. We've counted and sexed, like, I forgot what the number is, but like 100,000 something wasps, you know. (laugh)

Students gained a more realistic sense of the amount of time it takes to get research results.

> I learned how long an experiment really does take, how long progress takes, like you work a whole semester, you hardly make any progress.

One student discovered that doing research does not mean working in isolation, as she had thought. Finding that science involves working with others was important to her.

> Well I always thought, you know, just research in general, you're kind of isolated. It's not working with people or anything like that - and it's the exact opposite. I think science, you really do focus on group work and working with people and exchanging ideas. And that was one of the reasons why I was kind of dissuaded from going into research, because I like to work with people and talk to people. And you do get the opportunity to do that with research.

4. Students were able to experience the scientific process in a working laboratory. Many students spoke of how they learned to organize and conduct research.

> Now it's like, okay, if I want to start something I have to set up a hypothesis, I have to research background information involving it, and research procedures that have been used in similar cases. I know more about what I have to do to conduct research.

Many students found that the actual practice of doing research was complex in comparison to the theoretical scientific process that they had learned about in the classroom. This was particularly evident to those students who found their original hypotheses to be incorrect. Students found that actually carrying out an investigation resulted in finding unexpected problems that had to be overcome.

> And I just got a better grasp of that - propose a hypothesis, start doing steps to achieve it, then you run into hurdles, then you have to think over the hurdles, and then you run into more problems, then you've got to think to solve that and so forth and so on until you get to some results. I just got, I got a better handle on it, I just learned, I've learned that basically science is just trying stuff out that you think might be right and then when it doesn't work, try to solve the problems.

B. Most students reported that they gained confidence in their ability to do research.

Many students were interested in research prior to their experience. These students uniformly reported that as a result of their experience, they now felt that they have the ability to succeed in research.

> It was also successful in the idea that, okay, I'd never done real lab research before, and yet that was what I was thinking about going into. Now I realize what it involves, and I realize that it is something I can handle.

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> I know that I can set up my own research project. I guess that is probably about the coolest thing that I've learned.

One student felt that she can do research in other areas beyond the scope of her project.

> And I think I can do different types of things now. I don't think I'm stuck into a little niche on stomatas and plants, you know?

Students found that even though they did not initially know much about their mentors' research, they were able to develop their knowledge and abilities, and function in the lab. This process of development instilled confidence.

> I mean when I first went in there I didn't know what was going on, I never studied immunology or anything. After I got a base, knew what was going on, I could do it pretty good, trouble shoot or overcome problems well and everything, understand what was going on. First I was in the dark, once I learned it, it's not that difficult to learn, but once you learn it it's not really hard to apply, it's just a matter of learning the techniques, then you can apply and it's not that hard, all it takes is a little creativity.

****

> I built my confidence up, I got to know what I was doing, why I was doing it, I was understanding the procedures and the processes that we were doing and why we were doing it. Whereas when I initially started it I was just like, 'okay, I'll do this. I don't know why I'm doing it, but I'll do it.'

C. The research experience provided students with the opportunity to envision themselves as going into research, and aided them in deciding whether to pursue a research career.

Many students discussed how as a result of this research experience they could now envision themselves doing research as a career. For example, one student described himself as always being interested in science, and said that as a result of his research experience he found a type of environment that he wanted to work in.

> I'm getting all kinds of things at all kinds of different levels. I guess, from farthest away, the greatest thing that I'm getting out of this is just a place that, just an environment that is suitable to me. I think I've always kind of been looking for people like these to work with. I never really knew any of them closely, I never really knew any scientists in any kind of intimate way. . . So I'm receiving a formal introduction into the scientific community.

1. The students' relationships with their mentors were important in their feeling that they could find a place in research. As noted earlier, a few students commented on how their mentor made an effort to make them feel comfortable in the lab, and others commented about establishing a one-on-one relationship with a faculty member for the first time in their university experience. A few students looked upon their mentors as role models and identified with them.

> This was like being introduced to some relatives that I had never met before, almost. It was that important and that significant. [Two graduate students] are like my brothers in a way, in the scientific community, and it was very important for me to meet these people. I didn't really know any scientists before I went into [the mentor's] lab.

One female student found that she could look up to her female mentor as a role model of what is possible for women in science.

> As far as being a woman, I mean I think [the mentor], she's researched, she told me about her life and - so she's kind of someone I could look up to. Not to actually be like her, but someone who's done it. And she helps with other women in science. There's like a - women engineers in science kind of group that she helps out with. So I think she realizes the need for role models. So I think that's good.

2. Most of the students expressed an interest in doing more research as undergraduates. A few students were openly enthusiastic about the prospect.

> Oh yeah! I love the lab. It's great. I mean, I would stay, if I could, past this semester and just do research and everything, and the people are great.

Many mentioned the confidence they had gained in their experience as a factor in their wanting to do more research as undergraduates.

> The experience gave me more confidence to try more independent research. I want to do another independent project.

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> I guess it gives me more confidence--the fact that I would be able to approach, you know, another professor. . . about joining his research team or doing research for them, and . . . having the confidence that I would be able to do an excellent job for him.

Most students who wanted to do more research did not have definite plans, while others expressed an interest in continuing to work with their mentors. A few students were invited by their mentors to continue working in the lab.

3. Students became aware of different career possibilities and saw their experience as opening opportunities for them. One student who is planning to go to medical school and train to become a pediatrician spoke of how his experience enabled him to discover the possibility of doing research as a physician.

> Being in the lab I've really fallen in love with research. And it has really opened up the careers, the career opportunities before me. I didn't know a lot of the careers even existed before. And since I've been in the lab I've been exposed to more of the community, and

> gone to more lectures, and met more people, and seeing how diverse the careers are that people choose within science. And that there are pediatricians who do have children in their care at UW hospital and yet do research too, and use children as their subjects. That kind of career seems ideal to me at this point. I don't know if I would like doing something that was just primary care, like I thought I would before.

Many students talked about how they felt their experience provided them with opportunities they did not have before.

> I'm really glad I did this. I think it's definitely to my advantage, and it's opened up other opportunities for me also. So, like, next year I think I might work under [the mentor] again. So it's definitely put my foot in the door.

This student went on to discuss how she was introduced to professors in her area of interest by her mentor.

> If I tell him I'm interested in something, he'll say, "Oh, well this professor does research on this, and we go and he'll show you his lab and stuff." So, the people I met, that was a really important thing that I thought I gained.

A few students mentioned that their experience has made them consider going to graduate school.

> Yeah, yeah. I'm thinking about it now. So, actually this project had, I don't know, it put many ideas in my head of what I could do, actually. Because before I wasn't even considering grad school, I was just going to try and get on with the work force. I mean if not, go into the Peace Corps. And now I think that going to grad school might be a good idea.

One student was encouraged by her mentor to apply for a grant to continue working in the lab. Her experience made the task seem easy, "because basically I've written a proposal and a final paper already."

4. A few students were able to confirm their earlier beliefs that they were interested in a science career.

> I realize more that this is what I want to do, that I want to do research and things like that. He kind of directed me. I mean, I thought that's what I wanted to do, but now I'm pretty sure that's something that I'm interested in.

One student had recently decided to go into science, and his research experience affirmed his choice.

> R: It strengthened it. I know I want to go into sciences.

> I: You had switched fairly recently.
>
> R: Right, I'd switched, not last semester, but the semester before, from pre-law to genetics. It definitely made me realize that that's where I want to be.

Other students said that their experience not only confirmed their interest in a science career, but helped them realize that they were interested in the research area of their project.

> It helped me get experience in my field which was really - now I know that I really do like it.

5. *A few students came to realize that they were not interested in pursuing a research career in the area of their project.* Two of the students explained that they did not like the laboratory work because it simply did not fit their personalities.

> I definitely won't be in the lab setting, probably. I'm just not that type of person, where it seems like indoors is all right, I won't be outdoors or anything, but just, it seemed like we were really enclosed in the lab. We're in the lab all day, and they're looking at one little thing, trying to run an experiment here and there, and if it didn't work, you had to keep doing it again and again, and it just seemed like it just really wouldn't fit my personality.

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> Not something I want to do for the rest of my life! I think it definitely takes a specific type of personality to be able to do that kind of work and find it fulfilling and enjoy it. I like it for a short term, but as far as long term I don't enjoy it, I don't think.

Another student found that she definitely wasn't interested in her research area.

> That kind of helped me see what this area is like, and I don't think I want to see any more of it! It's interesting, but just not my cup of tea.

However, she did like doing research and the experience helped her decide that she wants to go to graduate school in another area.

> I think it kind of helped me understand what I want to go into now, so it kind of helped choose a career option for me, in a way. Now I'm heading more toward grad school than medical school.

Even though some students found that they were not interested in doing research in the area of their project, they thought their experience valuable. One student thought it important for the process of choosing a career that he was able to see for himself what laboratory life was like.

> I'm not, you know, particularly going to study immunology, but at least I got to see what scientists do, what their day is like, what they do, what kind of life basically they lead at work. I got to try it out, which is important to me because if I'm gonna choose to study science for a long time, which I may do, I want to know if I have a taste for things.

The Research Mentors' Point of View

I. Mentors' Goals and Motivations 1
  A. Mentors universally wanted students to learn how to think like a scientist as part of their general education and to prepare them for citizenship. 1
    1. All mentors expressed variations on the theme that learning how to think and act like a scientist is valuable for the individual and for society. 1
    2. Many mentors thought that the research experience teaches students universally applicable problem-solving skills, valuable in all fields. 1
  B. Mentors felt that students lack contact with faculty at large research institutions such as UW-Madison, and the research experience provides an avenue to address this situation. 2
  C. Mentors thought that the projects gave students an opportunity to gain an understanding of how science works by actually doing science. 3
    1. Mentors thought that having students simply see research labs in operation was valuable in itself 3
    2. Mentors stressed the distinction between research and classroom science. 3
    3. Mentors thought that the research experience showed students the day-to-day realities of doing research. 3
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        1. Almost all the mentors were positive about mentoring teams 22
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The Research Mentors' Point of View

In this section we will present the mentors' descriptions of their experience during the Fall 1995 semester. The main headings and sub-headings represent themes uncovered by our analysis of the mentors' interviews. Some of the themes arose from mentor responses to our interview questions. Other themes were brought up and discussed by the mentors without prompting by the interviewer. We interviewed five faculty who mentored teams and four faculty who mentored individual students after the semester ended. Six of the faculty had also participated in the baseline interviews conducted before the semester began. All of the faculty had mentored students we interviewed.

I. Mentors' Goals and Motivations

A. Mentors universally wanted students to learn how to think like a scientist as part of their general education and to prepare them for citizenship.

1. All mentors expressed variations on the theme that learning how to think and act like a scientist is valuable for the individual and for society. One mentor thought that gaining an understanding of science was the most important part of students' research experiences.

> When they pick up a paper, when they go to a voting booth and they vote on something, they know the value of what science can do, and they can appreciate what it takes to accomplish science. That, I think is maybe the most important contribution that any of these undergraduate research experiences can offer students.

Another mentor commented that for students to understand the value of thinking scientifically, they must work in the laboratory long enough to see results.

> I also tried to tell them that this is going to be a useful way to think in general. That kind of thing, I don't think sinks in. I think it only sinks in when they've done it enough times and they've actually gotten a successful result. Or disproven something.

Mentors did not confine their remarks to students who were going into science careers. They thought that even if students decide science is not for them, the experience is still a positive part of their education.

> They come away changed. They may decide they don't like that as a professional option, but I would hope that they would respect it and I would hope they would understand it in a way they could not otherwise.

2. Many mentors thought that the research experience teaches students universally applicable problem-solving skills, valuable in all fields. They believed that it is a "very useful kind of paradigm," one that can apply to "just about any problem you encounter." One mentor thought that learning how to objectively examine problems and test possible solutions was the central benefit of students' research experience.

> I think I can honestly say if they got nothing else out of the lab, or out of the 152 experience, except this notion of looking at a problem as objectively as possible, and breaking it down into the simplest explanations and then testing them systematically, then I think I'm doing my job. And they're getting more out of college than they might otherwise.

Another mentor spoke of students learning "transferable skills," useful in fields other than science.

> Transferable skills are essential as part of that whole package. If they become a lawyer they use some of the same skills.

B. Mentors felt that students lack contact with faculty at large research institutions such as UW-Madison, and the research experience provides an avenue to address this situation.

A few mentors spoke of the impersonal nature of a large campus, with one mentor commenting that some students never have the opportunity for personal contact with faculty.

> I'm afraid that a lot of students end up graduating never knowing or interacting in a meaningful way with the faculty.

One mentor had been an undergraduate at a university where undergraduate research was a tradition. He thought that there isn't enough undergraduate research at UW-Madison and felt its sheer size hampers students from understanding the resources that are available to them.

> It's just such a big ungainly campus. I've noted very, very low levels of undergraduate participation in comparison, at least on a percentage basis. I have to believe that one of the reasons is quite simply the large uninterpretable nature of the campus to any undergraduate.

Another mentor believed that offering a research experience is a strong suit of a large research institution like UW-Madison. He felt that doing research can make attending a large campus a more personal experience for students.

> I guess this is what a big campus has to offer. I mean a big campus like Madison is a pretty frightening place, and when I was an undergrad, I had no idea what was going on . . . It is so massive that I think students need to understand that there really is no such thing as University of Wisconsin. I mean there are colleges within the university, and departments within colleges, and labs within that, and before you know it you're in a team of people with 3 or 4 individuals so that you feel comfortable.

C. Mentors thought that the projects gave students an opportunity to gain an understanding of how science works by actually doing science.

In discussing this issue, mentors referred both to their current Biology 152 students and to their past experiences with undergraduate research students.

1. Mentors thought that having students simply see research labs in operation was valuable in itself. One mentor said that most students have a basic curiosity about research, which he described as wanting to know "what's this research thing." Another mentor described one of his students as coming to realize the complexity of research.

> In [the student's] case I think she had probably very little idea of what research was about. I just think it opened her eyes, that things are far more complex than she had imagined. The realization was bigger--"No, you can't go look that up in a book."

2. Mentors stressed the distinction between research and classroom science. One mentor explained that students can't understand science by being in classrooms, and need to be directly exposed to research in order to know whether or not they are interested in it.

> I just think that it's something you can't really show anybody in a classroom. It's the kind of thing that can only be achieved through seeing it. And some will love it, and some will hate it.

Another mentor said that most students don't understand that science is "an active, evolving field," and they must do research to understand what it is.

> You have students who are actively involved in doing science, and you're teaching them what science really is about. Science really isn't about definitions and endless lists of terms that you try and remember.

3. Mentors thought that the research experience showed students the day-to-day realities of doing research. A few mentors thought that students needed to see that research sometimes involves long hours of repetitive work.

> And I think that was a real learning experience for them, seeing science done on kind of a experimental design basis, but then kind of cross collating that with day to day work. And then the next step was drudgery. They had to come in, and learning how to sex a wasp was interesting, and then they had five hundred more to sex. And coming in and counting them and all that. There's a certain amount of drudgery and that's what science is - there's no getting away from actually doing it.

One mentor described how his team of students learned that they had to get through initial failures before they could make progress.

> There was a lot of variability. They were just learning. They got to see the process of, okay, their first experiments are all over the board. The results are just uninterpretable. Second week, things are making a little more sense, and by the third week they felt they knew what was going on and that they could move on to the next step.

4. Mentors thought that the experience would make science and scientists less mysterious and intimidating to students. Mentors remarked that students initially find laboratories intimidating.

> If you've never worked in a lab, you know even a place like this, it could be very scary. It's like, "Oh, look at all this equipment. It looks expensive. What if I break something?"

One mentor felt that actually doing research would "demystify" science for the students.

> I hope the notion of research is demystified a little bit, that basically research is just a glorified version of 20 questions.

A few mentors thought that students' experience of doing science and being in contact with professors help them see scientists as people.

> Well, I think one thing they get out of it is a feeling that some of the mystique about research in general and professors in particular is removed. I think they feel professors are approachable and human because, you know, just like during our conversation the phone rings and it's about picking up my daughter at basketball.

D. Mentors view the research experience as a way of bringing students into science.

1. Underlying many of the mentors' motivations is the desire to have students become interested in going into science as a career. Mentors viewed the research experience as an entree into science for students that the classroom can't provide. One mentor described students she has had over the years as "finding a home" and continuing to work in the lab after the initial work was completed. This mentor used the term "upbringing" to describe her process of gradually introducing students into science by showing them simple techniques and gradually having them learn how to ask questions and design experiments to answer those questions.

> One of the things that I normally do when a student first comes into the lab is, I show them how to do a bunch of techniques. You know, just real common; the easiest things that we do in the lab. And some of them are so simple that, I mean the students are stunned. . . Then they start on the experiments that will answer the question that they have proposed. And then once you get them to that point, then of course you know there's another level of upbringing when you begin to look at data analysis.

Other mentors who had long-term experience with undergraduates working in their labs spoke of how students develop an interest in science through exposure to the laboratory.

> Usually it's somebody who has worked in the lab for a while, and they start seeing an opportunity to carve out their own project that is totally theirs. You know, some students just go beyond the point of wanting to help somebody else and they want to have something that's theirs, and then they will get a summer credit for it.
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> ****************************
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> And so, in bringing students in, they're exposed to what happens in this environment: what do we do. So it's a slow education process because you only bring a few students in, but if you can get the right students, where they're going to make contributions themselves, they can make decisions about, "I've always thought about this, but is this really what I want to do? I can see this first hand and learn and challenge myself..."

2. Mentors are interested in developing future graduate students. One mentor spoke of his goal of "growing" graduate students for his own lab and other institutions.

> The other thing is the philosophy that you can "grow your own", if I can explain what I mean by that. By "grow your own", meaning that if you want to find good potential graduate students, you can grow and develop those graduate students out of undergraduates. And I don't mean just grow your own students for your project, although I have one of the students that worked for me last summer that will be starting as a graduate student this spring, but grow students to pursue graduate work in other institutions.

Though mentors discussed the production of graduate students as a reason they offer research to undergraduates, they realized the chance of a given student going on to graduate school is low.

> I mean realistically 99 percent of the people I teach in here aren't going to become PhD's.
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> **************************
>
> If you mean is it worth it to expose undergrads to research, and it is worth it in the sense that these--you know, I thought that these were two very bright, industrious kids--I think yeah, it's quite worth it. What they'll do? I have no idea.

3. A few mentors mentioned that their undergraduate research experience was critical to starting their careers. These mentors' own undergraduate research experiences were a motivating factor in their offering students a place in their labs.

> We had this independent research, basically myself and another student went with one of the professors out to a marine laboratory on the coast of Oregon and worked for four or five days. And it was - I just enjoyed it so much that I decided this is probably a good career for me.
>
> ****************************
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> And virtually everyone that I - I mean this is something that we've talked about at scientific meetings before - is that virtually all of us got hooked doing research as a undergraduate.

E. Mentors believed that their graduate students learn about teaching by guiding undergraduates' research projects.

A few mentors mentioned the value to graduate students of guiding an undergraduate student's research project. They thought it was an important part of their graduate students' education. Two mentors saw their mentoring as a dual process of teaching both their graduate students and the undergraduates.

> But, you know, I look at it from two standpoints. One is the undergraduate is learning something, and then secondly, the grad student, post doc, or technician has to learn, has to appreciate the teaching mode.

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> I was training these students but at the same time I was training [the graduate student]. He'd never done anything like this before, and so there's more - it's more of a training web then maybe they think.

Another mentor discussed what his graduate student got out of mentoring the Biology 152 undergraduate. He felt the task was good preparation for the graduate student's future as a university professor.

> I think it was definitely worth it to my graduate student. I think it's an extremely valuable experience for him. He wants to be a teacher. He wants to work at an institution where he has a lot of contact with undergrads teaching, so it's definitely worth it from that point of view. I could see him, sometimes struggling, but benefiting from working with another individual in this way.

He thought that graduate students need the experience of mentoring undergraduates to learn personal interaction skills.

> I would say that some graduate students could come through here and could become very efficient at certain things and be very good in the sciences, but they're not necessarily good at personal interaction, and this gives them an experience at personal interaction one on one with a student. See, it's my job to mentor these graduate students, now these graduate students are getting a little experience at a mentoring project as well.

II. Role of the Mentor

A. Many mentors saw the need to make their students feel comfortable and fit into the lab.

Many mentors felt that students in general are initially intimidated by being in a research laboratory for the first time, and need to go through a phase of adapting to the laboratory environment. One mentor felt that students are hesitant to ask questions because of not knowing anyone in the lab.

> And that's something that's funny that - you know some people come in and are kind of shy, they don't know what the social context is. They don't know who they can bother about a problem and to kind of get them through that and sort of realize what it's like being in real laboratory.

Another mentor thought that his three students were afraid of making mistakes and failing.

> They were kind of scared too, I mean this was their first project and I think the fear of failure is a pretty powerful force at peoples' first research experience and you can't underestimate it. So I think they'd come in and you know, the main thing on their mind is "Gee, I hope I don't screw everything up and look like an idiot." And you sort of have to get past that.

One mentor consciously tried to make his students feel comfortable but thought that their limited time in the lab hampered this.

> R: I wondered about that a little bit. I know that was actually an objective I had--to have them feel like they fit in.
>
> I: You were conscious of trying to fit them in?
>
> R: It isn't easy to do when they show up on these very rigorously scheduled sort of appearances. I can't remember when their schedules allowed, but it was like Tuesday at 1:00 that they could show up. It depends on what else is happening. It's not that many sessions over a semester--so it's tough for them--and they're quite young.

A few mentors invited students to make the lab a place where they could come to socialize or to study, offering the use of computers. One mentor clearly thought of his lab as a social place, a "hang-out."

> Yeah, I mean you can look out the door -- it's kind of a hang-out. They're all working very hard; they may look like they were having fun, and hopefully they are, they're listening to the radio -- (I: they look like they're working hard, actually!) -- they're- you know, they've made coffee...and Pizza Hut sure knows this place by heart. But they get a lot done, and, yeah they feel like they belong.

A few mentors expressed mixed feelings about whether their students felt that they fit into the lab. One mentor of a team of three thought that two of his students were shy and apprehensive, while the third student "fit right in." Other mentors thought their students had adjusted to the lab and felt comfortable.

> I think she was comfortable in there. She felt like she could come and go when she needed to. She knew everybody in the lab. She knew the graduate students, and ______ and ______ were the specialists. Before, just before the end of the semester we had a social out at my house and [the student], as a member of the lab group, was there with all

> the other people. I mean, I considered her part of the lab group. So, I think she felt comfortable, or was comfortable with the other people. She is an easy person to get along with and talk to.

Most mentors had lab meetings for their research group, and invited students to attend, but students generally did not attend because of time conflicts.

B. Mentors varied in how they involved students in the selection of a research project.

1. Mentors varied from assigning a project to students to giving them a limited choice of projects that would be appropriate for their labs and for the students. One mentor described to students the possible projects in his large lab group and allowed them to select what they were interested in - or decide whether they were interested in working with him at all.

> And then I outlined the types of project directions--we have a group right now that's about four post-docs and three graduate students and anywhere from two to four technicians depending on how you count it, so it's an operation that has a number of facets going on, and I just told them about the different project lines. I said, "I would like you to think about what's most interesting to you, go away, and tell me in a week are you interested or are you not. And then which way should we talk more about?"

Another mentor had decided that students would work with a gypsy moth parasitic wasp, and gave students a choice of questions to investigate.

> So I laid out a bunch of questions and said, "Here's an example of some of the kinds of questions I think you can reasonably answer within a one semester period." And then we talked back and forth and they decided what would be effect of egg nest size and wasp density on production and sex ratio of this wasp.

A few mentors said they simply gave the students their project. One of them explained that his research area was too complex for students to be able to formulate a project.

> We supplied the project. It's fly genetics that's so esoteric that I doubt that any of the people could come up with it on their own.

2. Whatever the method of selecting a project, many mentors had students decide what they wanted to investigate about the phenomenon and how to go about doing it, rather than laying out the details of the project for them. One mentor was pleased that his student came up with additional questions to investigate.

> And so [the student] had to think about what we were doing and actually she came up with several hypotheses beyond what we had. I mean the basic hypothesis was does this disk reflect the plant, but then she started asking questions about, well does the place on the leaf where you take the disk matter?

Another mentor felt that having his students design their project was an essential part of their experience.

> R: The simple way around it is for me to hand them a project on a platter and say, "This is what you're doing, this is what it means," but that's, that's intellectually bankrupt and it's, it's just ripping them off.
>
> I: So what did you do to get them started?
>
> R: Well, just had them look at the phenomena and tell them general ideas about the sort of things that were thought to be going on. And then had them - well first they had to formulate their what they thought what the hypotheses were. And then they had to design the experiments to test them. Took a lot of prompting. I mean I can't pretend that, you know, they're coming up "Well, why don't we use this specific inhibitor?" But we did manage to lead them, "Well how would you go about doing this?" There were times we had to go all the way back to, well the DNA makes the RNA which makes the protein. But I think they learned that kind of biology much better for being put in the hot seat.

C. Most mentors tried to select projects that would be suitable for their inexperienced students.

The research areas in the mentors' laboratories ranged from working with visible organisms to molecular biology. Since mentors offered students projects working within the area of their laboratory, project selection was limited. Nevertheless, most mentors made decisions about projects so that students would get the maximum benefits from their research experience.

1. Many mentors thought that students should have a project involving a question that could be fully investigated in one semester. These mentors thought that students should experience a sense of completion at the end of the semester. One mentor had students do a project with a gypsy moth parasitic wasp in which they could "really get something done." Another had students looking at the effects of crystal formation on leaf stomata, a project she thought they could complete.

> I know I've put together an answerable project, that I know they can do. And that's important, that they be able to come up with an answer.

2. A few mentors discussed the problematic aspects of designing a project in their research area that was suitable for a one-semester first research experience. Mentors described projects in molecular biology as generally involving complex techniques and being incremental in nature. One mentor commented on the nature of this research area, pointing out that projects in this area often limit students to learning techniques rather than testing a hypothesis.

> And, I've tried to come up with those [projects], or move the student into a reasonable arena so they could test the hypothesis, but often times, the hypothesis turns out to be

> more than can be accomplished in a semester. Usually, in a semester the student learns tools, techniques. That's about it. Can I take, let's say a piece of DNA and put it into a plasmid vector system? Can I culture cells and show that these cells will respond to an antigen, or these cells have a particular phenotype, or characteristic, can I do that?"

Another mentor commented on his past experience with students doing molecular biology projects: students were disappointed because they couldn't get meaningful results.

> A lot of molecular biology, there's a tremendous lead time before you have interesting results. So, initially I put the first two students I had on molecular biology projects. And I realized at the end of the semester, they really don't have that much to show for it and I think they're a little disappointed.

Drawing on this experience, he decided the students should investigate a phenomena they could actually see, cortical contraction in frog eggs.

> And they're so big you can see them with a dissecting microscope and you can poke them around a plate with your forceps. Very, very accessible to students.

He thought that students would find working with visible phenomena more meaningful and stimulating than working solely at the molecular level.

> So, it tends to be very abstract, rather than an obvious biological phenomena. You get a little band on a gel, and what does that band mean. I can tell them what it means, but that's not the same as them looking at it and saying "Oh, what's this?" They can look at it and say - and start thinking immediately about "Well, what's going on here?"

Another mentor, whose students worked in neural chemistry, thought that inexperienced students needed a project that had a "cookbook" approach in order to be able to work in his difficult area of research.

> Amino histo-chemistry is something that is as close to cookbooking as we can get. In other words, it's dead tissue, you need to be religious about your timing and your application of the different anti-bodies or this, that or the other thing. But it's something that someone who is careful can get a pleasing result from and see it in a fairly short period of time.

One mentor was not satisfied with the project he gave his student: doing a computer analysis of bluebird breeding data. He thought his student did very good work, but felt that the one-semester time frame was too short, and students need to get out into the field for the data analysis to be meaningful. For these reasons, he is reluctant to mentor another Biology 152 student.

> I often think that maybe for some of these students the projects that I offer might not be the best things. I think to really instill interest in a lot of these students, I think maybe hands-on projects are better than some of the things I'm offering for them, which are

> really data analyses, computer intensive stuff. . .I'm very interested in making sure this is, like I said, a meaningful experience, and I'm not convinced that the time allowed in one semester lets me interact with the student over a long enough scale that they really get out of the experience what I want.

D. Mentors provided different ways of structuring the students' research experience.

Mentors had differing philosophies about the type of guidance that was suitable for their students and exhibited different styles of mentoring in working with their students.

1. A few mentors consciously wanted students to take some responsibility for their own learning One of them had her students working independently of her and refrained from giving them explicit directions.

> I also believe in this very much, in this whole idea of students taking responsibility for their own learning and getting away from the, "Oh, just tell me what I need to know." I just ask them questions. I just won't let them get away with them sort of saying, "So now what do I do?"

Another mentor held weekly meeting with his three students in which he guided them as they made decisions, but refrained from giving explicit directions. He made himself available to students by working in the lab when they were there, but did not actively direct their lab work.

> Yeah, so my role was more often to just come in and, you know, be the one-man peanut gallery and sit down and work in the same room with them doing something different and help them trouble shoot. But, it's not as if I would say, "Okay, now I'm going to take you over here and you're going to learn this." It was more like, I tried to be around, but...

2. Most mentors allowed students to work relatively independently with a minimal amount of direct supervision by the mentor. Mentors spent time with the students, assisting them in getting started on the project. After this initial phase, most mentors had the students work largely independently of them.

One mentor was involved with the students at the beginning and the end of the project, and met with them often enough to "keep in touch." At times he would help them in the lab when the graduate student who worked with them was not available. He also relied on his large research group to help the students.

> But when I felt at one stage that [the technician] was unavailable to them--I'd see them sort of wandering around the lab and--I just started talking with them, "Are you getting adequate help?" and whatnot. . . So at that stage it was just a management thing, trying to make sure that some of the others knew that I would like them to take a responsibility to talk them through a few things and whatnot. They were happy too. It's a group that actually likes and seeks teaching kinds of interactions.

Another mentor did not meet regularly with her two students after she had gotten them started on their project, and rarely saw one of them because of the student's schedule.

> I knew he was coming in and working because sometimes he would leave me notes done on the blackboard, and I knew I left at X time, and it would be there at like 8:30 the next morning. So I knew he had to have been in that time period. And sometimes it was happening on the weekends, like between Friday night and Saturday at noon.

One mentor was out of the country for several weeks at the beginning of his students' project on analyzing bluebird breeding data. He left the student instructions and reading material with which to get started. After the mentor's return, the student worked largely independently, meeting with the mentor as needed about every two weeks over the semester.

> I would give her backgrounds. I'd give her short lectures on why it was an important problem, how you might approach it. I had to teach some basic ideas about statistics. . .I mean, she was someone who I could meet with for an hour, an hour and a half, and she'd go away and do everything I suggested she'd do.

3. Mentors structured the projects to varying degrees through hypothesis formation and testing. One mentor had his three students begin their project by generating hypotheses and testing them, and discussing the results and technical aspects at their weekly meetings.

> Basically the idea was first to allow them to generate hypotheses at these meetings and the ensuing week test them, and then on Friday go over how far they got and what their results were, or what technical difficulties they were encountering.

After some initial experiments, he had student read and formulate hypotheses to test in the remainder of their project.

> I sent them to the library and said, "Now I want, I've given you enough information, I want you to spend, instead of this week spending it in the lab, I want you to go to the library, and on Friday to come back to me and I want you to all have formulated some hypotheses about how this might be working based on the literature."

But other mentors pointed out that molecular biology projects are sometimes difficult to structure in terms of hypothesis formation and testing. One mentor thought that testing hypotheses is "more than can be accomplished in a semester." Another mentor whose students worked in fly genetics described the project as "lets go out and see what weird mutants we can find." He thought that the project was not appropriate for formulating a hypothesis.

> But it's not really hypothesis testing in any sense. It's not like it's giving them a great feel for scientific method or anything. The problem is in our field the hypothesis are just so complicated that to really test a real one, would I think strain - you know it gets really pretty difficult.

4. Mentors varied in their structuring of students' research using goals and timelines. Most mentors did not discuss specific goals or a schedule with the students, and allowed students to work at their own pace.

> I'm pretty laid back about that kind of thing. And I don't mind being a cheerleader, but I'm not going to be the guy, I'm not going to be the whip master or whatever. So what I tell them up front is, you know, I don't expect you to punch a clock or anything.

In contrast, one mentor believed it important for students to understand the structure of the semester's work in order to achieve their goals. Time management was an important aspect of science for this mentor.

> Once we worked out the questions, we worked on the experimental design together, and then we pretty much turned things on 90 degree angles and had them get into the issues of time management and planning that were involved. And that's a big part of science. I mean, we think of the creative aspect of science, asking the question and devising an approach but then once you've done that, you've got to decide, "What am I gonna do on Monday? What am I gonna do on Tuesday? And what do I do first and what do I do second?"

The mentor made the students see and plan the whole semester, starting from the end and working backward and filling in the steps. This galvanized the students, as they could see the amounts of time allotted to each phase and the necessity of completing steps efficiently. His approach contrasts with those of most other mentors in his detailed planning to achieve specific goals.

> I think it was a real eye opener to them that we could sit down in late September and plan out the whole semester. And I think when they saw all that ahead of them, they felt. . . they better run down to the lab and start getting some things done. It was interesting to watch them see their research calendar fill up from the back, you know, from our objective which was approached here, all the way back to what the check points would have to be.

5. Mentors shared their role of guiding the students with others in their lab. Most mentors had the students work with a graduate student, technician or post-doctoral fellow after the introductory phase of the project was completed. They viewed their role as one of overseeing rather than closely monitoring their student.

> So the technical procedure of things [the graduate student] did with [the student]. I think it was more my role to try to make sure that we had a reasonable project, that she understood the project, that she was carrying it in the direction I thought it should be going in, that she wasn't getting off track somewhere along the line, that she understand what she was doing.

One mentor thought that the undergraduates benefitted in seeing the "different levels of science."

> But it's also important that they see, you know, behind the different levels of science that people are going through.

Aside from mentors' belief that mentoring was beneficial to their graduate students, the shared mentorship seemed to be necessitated by the work load of the mentors: they simply did not have time to guide students in the day-to-day lab work.

III. Mentors' View of Students and their Research

A. Most mentors viewed their students in a positive light and were pleased with their effort.

1. Most mentors had praise for their students, with many thinking that their students performed exceptionally well.

> She's extremely bright. She's probably the hardest working undergrad I've ever come across.

Most mentors described their students as mastering the techniques necessary to get results.

> So I was kind of amazed by the end of this semester how comfortable [the student] seemed to be sitting down with this camera and microscope and cables and all of this, and sit down at the computer and then click click and there's a picture of the disk and click click there's some more things going on, and then she could get some data.

Many mentors thought that their students had helped advance their lab's research, an area discussed later in this section.

2. Two mentors indicated that they had students with whom they were not pleased. One of them did not think the student made a sufficient effort, and contrasted the student with his Biology 152 research partner.

> My perception was that the level of energy that he put into it wasn't the same as what [the other student] did. There were some serious consequences at the end of the semester when it came time for a letter grade....it wasn't with the level of enthusiasm, and it wasn't with the sort of commitment that [the other student] had.

The other mentor expected his student to know far more than the student did, thinking that "he could step in and begin to do things in the lab." This was the mentor's first experience with an undergraduate in his lab. As a result of his misunderstanding of the student's level of knowledge and experience, the mentor felt he had to spend an exceptional amount of time explaining basic ideas to the student. The student did not do an independent project but watched and assisted others. "I think what it really means is I didn't screen him adequately." In retrospect, the mentor thought his lab was an inappropriate place for a beginning biology student. "We're talking about something here that's beyond the level of a standard intro biology course, by a mile."

B. Mentors believe that responsibility, commitment, and curiosity are key student characteristics for success in the research lab.

Virtually uniformly, mentors brought up responsibility, commitment, and curiosity as the characteristics they considered essential for a student to be successful in the laboratory.

> R: I guess I would want them to be curious.
>
> I: O.K.
>
> R: The more the better. And I think they'd have, also have to be responsible, I think, because you can be curious but if you're not very responsible you're not going to get anywhere. You know, it does take effort. And, those, I think, those two attributes are probably more important than intelligence.

A few mentors took the characteristic of curiosity a step further, wanting students to be interested in their area of research. One mentor thought it critical that students consciously choose a lab they are interested in rather than being assigned to one.

> I guess I think it's important that students have a lot of responsibility in choosing a lab rather than that they be assigned a lab. . . that was one of the things that helps students buy in and one of things that I was looking for here. Of the first three that I interviewed, it seemed pretty clear to me that [the student] was genuinely interested--especially after we talked the first time. . . I tell them fairly bluntly, "I think it's important that you want to be here, because you're going to waste my time, you're going to waste your time, you're going to learn much less. It's really important to be where you think you might be interested."

Another mentor discussed his concern with responsibility and spoke of previous experiences with undergraduates who are not committed to their research.

> Day one, when they come and sit down, I'd say, "The most important thing that you are going to do here, what I need from you is to be responsible. By being responsible, that means that you meet your commitment, that you do the tasks that you say you are going to do today." They might come in, "Well, I want to do this project." Well, will you be here next week and the week after that, and the week after that, will you make that commitment of being responsible? Because in the past, I've had students who say, "I want to do this great thing!" They come to the first week, and, "Oh, I've got this exam! My girlfriend is in the hospital," you know, all of these other things, and "Gee, I want to

> go to Purdue for the basketball game." . . . I'm just saying follow through on the commitment. Be responsible. That's the highest priority that I have for the student.

The importance of scientific knowledge and intelligence were downplayed by almost all mentors.

> As far as advanced training within physiology or neurobiology--I don't consider that necessary at all...Intelligence helps, but it's not the end-all I think.

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> No, no, because it's not important that you have a knowledge of the material, or that you take away from this a knowledge of the material. . . No, you don't have to have high intelligence to observe and put your hands on science, no. And, as a personal observation, sometimes the people with the highest level of intelligence never accomplish anything.

C. Mentors had differing descriptions of the scientific value of their students' work.

1. The mentors' universally characterized their students's work as actually doing science rather than simply carrying out an educational activity as in a science course lab. They discussed how the students were formulating questions and designing experiments, experiencing frustration and success in a real situation, and sometimes finding unexpected results. A few mentors reported that their students found something unexpected.

> I think she'd seen it several times while I was gone, and then when I came back and was in the lab she said, "You know what I found? I found. . ." And I said, "Ooooh." And she said, "Didn't you tell me that that's not supposed to happen?" And I said, "Hmmmm (laughs)." So then we sort of modified the project based on her observation.

Two of the mentors have previously published work with undergraduates who have worked in their labs.

2. Though they view their students as doing research, most mentors do not expect publishable data from their students' work.

> I used to take the view that these students could provide some new information. I don't take that position anymore, after a number of years of experience. They can't generate themselves, as I said, publishable data.

****

> Someone brought this up at a faculty meeting one day and said, "We'll haul these undergrads in and we'll have them to publish all of this and isn't this wonderful." And I had sort of questioned how it had worked with undergrads, and I would say it's a very inefficient way to get publishable material.

3. Mentors felt that their students' work was of value to their lab. Despite not being able to use undergraduates data directly in a publication, many mentors felt that the students' research was a valuable initial investigation that would be worth replicating.

> Because of the way they did their experiments, I don't think we could ever use the data. But it at least tells me our hunches about something are probably right, and if we want to go back and prove it, it shouldn't be too difficult. So it solidified our understanding of what's going on. Which is no mean achievement, I think, for three untrained undergraduates.

A few mentors said that the students did preliminary work in an area their lab was planning to investigate. One mentor described his students' work as a "stepping stone".

> When we went into it, we were thinking kind of a pilot project, see what's out there. And there's a more sophisticated way of doing it which makes it easier to pursue in later steps, that we just were going to use it as kind of a stepping stone to get to that. We got enough interesting stuff out of it. I think there is at least a couple mutations we got now that we're going to go after.

He has organized his research so that undergraduates can contribute to the effort.

> I guess we've been doing it so regularly that it's sort of a given that we have these projects now that we can plug undergraduates into, and we know that they can do them, and we know that they can contribute to the laboratory if it works out.

Another mentor described his two students' work as "trying to establish some new directions." His lab will follow up on their work.

> It'll be implicit within another protocol. We're gearing up to do it, quote, "right" with an adequate sample size and all that.

D. Most mentors felt that when measured strictly by research results, mentoring undergraduates is costly in terms of their own and their lab personnel's time.

In discussing this issue, all mentors except one were referring to their past experience in general, rather than commenting on their current Biology 152 students.

1. Mentors felt that mentoring has a cost, and measured the cost in terms of their and their graduate student or lab technician's time. Most felt that the research results the undergraduates produce were expensive in terms of time. One mentor said that from the standpoint of contributing to his lab's progress, "it's not what you would seek for efficiency." Mentors were acutely aware of the time that mentoring undergraduates takes and are sensitive to the demands on graduate students. One mentor described the demands of working with two students on his graduate student.

> So they had separate schedules, so that made it difficult for the graduate student who was working with one to find the same time to work with the other one. And grad students, like you and I, have other commitments in their lives, and so they are trying to meet their own deadlines and schedules and commitments and classes....

He spoke of his long experience with graduate students and technicians mentoring undergraduates.

> I would say all of the graduate students and all of the technicians that I have ever had in my lab that have worked with undergrads, and post-docs as well, they all complain that these students take a lot of time, and the end result usually isn't publishable data.

Another mentor believed that his graduate student did not complete expected research work and publications because of the time spent working with the student.

> What was probably the case with my graduate student, he had two publications due that he didn't finish...Yeah, I know this publication thing is kind of kicking my butt, this semester. I mean, I have a suspicion that I'm going to be told that they should have been completed by the end of this semester.

2. A few mentors perceived their work with undergraduates as outside of their main responsibilities. Mentors said they were extremely busy with their teaching, research and administrative responsibilities, and two of them expressed some degree of guilt in mentoring undergraduates. One described the enjoyment he gets from watching students learn to do research as "selfish."

> Alright, teaching is inherently fun too. Um, it's a real charge. I don't know if this makes it selfish too, but I get a big kick out of it when they're struggling through their data, they're looking to me, what's going on here? And I just sit there with my arms folded. "Yeah, what's going on here?" And then they come up with an answer that's, you know, right on the money or, you know, close enough. Or even, like, totally off in left field. That's a blast.

The other mentor described his mentoring in terms of a "vice," explaining that it is detrimental to his research and other responsibilities.

> I guess if you wanted to look at it in a cold-hearted way, my interest in doing this is a form of a vice. I mean in that it definitely takes away from everything else.

3. Many mentors spontaneously brought up the pressures they are under to get research results which will ensure career advancement and further funding of their labs. They felt these pressures made it difficult to mentor undergraduates. One mentor spoke for his colleagues who won't have undergraduates doing research.

> So let me give you- let me just wear a different hat. Now I'm a different professor, and you come to me and you say, "I've got these students in 151 and they want to work in your lab". And my response is, "Absolutely not! I'm funded by NIH, NSF, and all these other funding agencies, to accomplish goals, goals of those grants. To accomplish those grant goals, I need to have my technical people working all the time, and now you're asking me to convert that time to work with undergrads who aren't going to generate data, who aren't going to generate manuscripts, who aren't going to support the grants that these people are supported on, ... why should I spend my time doing that?"

An untenured mentor remarked that mentoring won't advance his prospects for gaining tenure because it is not valued in making tenure decisions.

> And when the judgements are being made and people's records are being weighed, their contributions to those experiences, whether it's for this class, or the other students who just walk in and say "I want to do an independent study experience and I'll sign up for a credit with you." I want it to be a part of the, the weight. And right now I would say again, that wouldn't probably carry a lot of weight because we are such a research-minded institution.

Another untenured mentor agreed with this, pointing out that faculty are encouraged to work with undergraduates, but are not rewarded for it.

> You know, we're encouraged to participate with undergraduates in many ways verbally, certainly by the administration. But I sense that it won't pay off when it comes up to review with the biological science committee and tenure evaluation.

4. Though mentors do not think the undergraduates' research results are worth the time and effort in the strict sense of producing publishable data, they will continue to mentor students.

> They do take time away from you. But for someone who is receptive, for someone who's willing to play the game, at least for awhile, with me, I'll do that, and I'm willing to invest time in them.

A few mentors described the enjoyment they get from having undergraduates in the lab, with one saying that they are fun and enliven the laboratory.

> I kind of like the idea of just bringing new blood into the laboratory every once in a while anyway. . .I don't know, it's sort of fun to have new faces in the lab and new energy in the lab. And they're trying things out. And they jostle the grad students and that sort of increases the density of the laboratory.

Though mentors feel institutional pressure to get research done and grants written and accepted, they also seek personal satisfaction and have broader educational goals. They do not see the issue as one of cost/benefit in a strictly economic sense, but believe that the value of mentoring lies in the other areas that have been previously discussed under Mentors' Goals and Motivations.

IV. Mentoring Teams

Except for Part C, this section reflects the thinking of the five faculty who agreed to mentor teams. When contacted prior to the beginning of the semester, these mentors expressed an interest in working with a team of students. They thought working in teams was a common research practice and expected the team experience to work well.

> I think science works much better when you have several people thinking about the same thing. And this will be a more realistic scientific situation for them. People tend to have complementary ideas. . . And the reality is even in small labs like this one, there are several of us thinking all the time about a particular problem or subset of problems. And when it's working well, we're discussing them, we're batting ideas back and forth. If that's not happening, I would argue it's not being done right.

A. Mentors described several ways in which their students benefitted from working in a team.

1. Mentors said that the students in teams offered support to each other that made the experience less intimidating. Students in teams were a "buddy system" and helped each other find their way through the experience, relieving the mentor of some responsibility.

> I think there were times where one or the other might have gotten lost. I think it helped that they have a buddy system . . . I felt less obligation because they seemed OK. I felt less obligation to try to make sure they were finding their way through, because they seemed to be able to do it this way.

Being in a team made students feel less intimidated about interacting with the mentors. One mentor thought that students felt more comfortable during meetings with him than they would have alone.

> We sit and have a group discussion instead of me sitting there trying to ring questions or comments out of one person who's generally very intimidated. So in that respect it helped a lot.

Another mentor echoed this idea, saying it was easier for the students to approach her together with questions.

> They feel free to check with one another first if there's sort of something that slipped through the cracks that's still a question. So if they can say, "Did you understand what she meant?" And if the other one says, "No, I'm clueless," then it's O.K. Then they can say, "Now, what was it you were telling us about? Neither of us seems to have gotten it." Then it's O.K. to come back to me.

2. Two mentors reported that students taught each other. One mentor, whose students' schedules had them largely working separately, described teaching a technique to one student and having the student teach the others.

> But what would often happen is [first student] would learn the technique and then be able to teach it to [second student], and sometimes [third student] would come in for a little bit and they would both teach him. So, they were teaching each other, which I think is exactly the way it should be.

Another mentor reported that one student did not initially learn what he was to do and fell behind in his work, and the other student helped him catch up.

> I don't know what was happening in [the student's] life early on, but somehow I think he got himself a little bit behind the eight ball, and then shazam, I disappeared. And he was a little bit left in the lurch, and that created the proposal problem. And then when I came back, it was clear to me that he didn't quite have his act together, even though I had showed him before about how to do some of these things, and I think I might have said to [the other student] something like, "If you have time, could you help him out?", or maybe, "Could [the student] maybe help you do part of this? You need a lot of samples, and if he can help you prepare a lot of the samples, maybe you could sort of share." I mean, I tried to do it without saying, "Can you bail him out, cause I don't want to go through and sit down and teach him again."

3. Most mentors thought that the students accomplished more together than they could have individually. One mentor favorably compared his team to his previous research students who worked individually.

> Just sitting back objectively and seeing, comparing the results generated by those three to the results by all of the previous ones, I would say person for person they, they did a lot more.

Another thought his students had complementary skills that they contributed to the team effort.

> I think it worked out well in the sense that they have different skills. One individual was more comfortable with computer entry of the data and computer graphics than the others, one was more comfortable with - in the confidence of his identification of insects, and they had complimentary strengths. And one was a better writer than the others, so I think they synergized a bit there. I think it was a team effort, not just each one carrying one-third of the load, but each one carrying different parts of the load.

One mentor, however, was unsure about whether his team accomplished more than they could have as individuals. He thought that the answer would depend on the individuals involved.

> If you have a student that really was independent and driven, and they were alone and it was clear it was in their court, I can imagine they would make bigger progress at that. On the other hand, most students probably wouldn't.

B. Almost all mentors were positive about their experience with students working in teams.

1. Almost all the mentors were positive about mentoring teams. One mentor was enthusiastic about his experience, saying "I'd do it again in a heartbeat." Another mentor thought he learned from the experience.

> Yeah I would do it again...Yeah, yeah I mean - as a matter of fact, you know it wasn't just the students and [the graduate student] who was learning, I was learning and I think I could do a better job next time. So I mean there's some things that I learned about this too.

One mentor thought his team functioned well, but offered a suggestion: compose teams so that the students' schedules coordinate better. He met with his students as a group each week, but they worked separately much of the time.

> What would typically happen was [first student] would come in on Monday and work Monday and Tuesday and then [second student] would come in little bit on Tuesday and some on Wednesday and then [third student] would come Thursday or Friday.

None of the mentors indicated that they would be hesitant to mentor a team again.

2. Two mentors thought that working with a team was more efficient in terms of their time compared to working with the same number of individual students. As seen above in section A, mentors found that students would teach each other. One mentor even thought that working with three students was very efficient, possibly taking no more of his time than an individual student.

> I would say I spent probably less time with those three than I had with a couple of individual students.

Another mentor found some efficiency in teaching lab techniques to more than one student.

> But it's nice when there is two of them--they get to see the same thing. We don't have to coordinate quite as hard. So I think there's some efficiency there....

One mentor found it hard to think about comparing the efficiency of dealing with his team versus an individual, since he designed the project for three people.

> It's hard to estimate because I wouldn't have come up with this project. When I designed this project I had a threesome in mind.

3. *One mentor did not seem to think that his two students functioned well as a team.* The mentor described one student as a willing worker and the other as joining the project very late and not showing commitment.

> So, it was then at least four weeks, probably, into the semester, and he hadn't heard from [second student].....So, eventually they got together, but it was a long time before [second student] really got involved, and I wasn't really ever clear why there was this hiatus of connecting, because [first student] was a very, he's a gung-ho kind of person, willing to really learn, and he found this an interesting and exciting area, and wanted to do it.

C. Some potential mentors did not want to mentor teams, citing the pressures of their work loads.

Six faculty members were asked if they would mentor teams and declined the opportunity to do so. These faculty members did not mentor any Biology 152 undergraduates in the semester under study. Several of them couched their discussion of why they did not want to mentor a team in terms of the pressures they are under to get research results. They agreed with mentors on the costs of mentoring undergraduates, regardless of whether the students were individuals or teams.

> An undergraduates knocks on the door and says, "I want to work at your lab, and I'll work for free!" Uh, is that a good deal? The answer is no, the answer is not a good deal. They cost you. Because they don't have a clue, and someone will have to train them! And the person who will train them will be someone who already knows how to do science. And so the net productivity of the lab goes down.

One faculty member pointed out that she can't compete for grant money in her field with graduate students and even post-doctoral fellows. She is moving towards using staff scientists, and finds having undergraduates in her lab an increasing difficult proposition.

> Every three to five years I have to write to the NIH and I have to renew that grant. It takes sometimes two years to get them through. I make them a series of promises for what I'm going to do, and if I have not achieved everything that is on that, I don't get refunded. It doesn't matter how much I've taught, it doesn't matter how many lives I've touched. This is totally irrelevant....When I bring undergraduates into the laboratory it's even worse because there's zero guaranteed productivity. You're doing nothing except educating that student. There's no other value to the research program for doing that, and that's a fact.

In addition, she thought her lab was unsuitable for teams "just because of the dangers" from biological and radiation hazards. She feared that students working together would be more likely to get into trouble than an individual.

> Two of them together would reinforce each other and do more stuff that's worse. I don't think it would be positive, I think it would be negative.

Two faculty members thought that having more than one undergraduate would be too much work for them.

> There would be two people to worry about, you know...It doesn't quite double the work, but it certainly increases the work a lot.

One of them thought that the students' schedules probably wouldn't coordinate, and this would preclude any time efficiency.

Another faculty member didn't see any advantage of students working in teams, explaining that he feels it necessary to pair undergraduates one-on-one with a graduate student. He discounted the undergraduates' ability to help each other. "They're not going to learn techniques from each other, really."

Though these faculty members saw the benefits to undergraduates of having a research experience, they uniformly felt that their present situation precluded mentoring teams. The pressures of their work loads were too much for them to consider the responsibility of mentoring a team.

V. Mentors' Views on the Proposal and Poster Session

A. Mentors felt writing the proposal was essential for students to understand what they were doing.

1. Mentors felt that proposal writing helped students understand the nature of scientific research. One mentor thought that writing the proposal makes students realize that the answers to scientific questions aren't already known.

> It makes them get used to the idea that you don't get all the answers in advance, and you can't go look them up. They would ask, "Where can I read about this?" And I'd say, "These are things that are related, but none of them will tell you anything about specifically what we're doing because nobody has done this before." So that confronts them along those lines.

Another mentor said that students learned a key aspect of science, formulating objectives, in writing the proposal.

> That's absolutely essential, I mean that's the biggest thing you'll learn about science is how to formulate your objectives, and we went through a couple of iterations on that.

2. Mentors thought that the proposal writing helped students understand their project and the questions they were addressing. One mentor said that students need to gain an understanding of the central question in order to see why they are conducting experiments. Writing the proposal is an excellent way of assisting them in gaining this understanding.

> Oh, it's excellent...I think they have to do it...If the kids are really going to get as much out of the experience as they can, they really have to understand what the central question is. And if they don't understand the question, then why should they do this stupid little experiment?

Another mentor agreed that writing is critical for understanding, pointing out that students can do experiments without really knowing what they are doing.

> I think it's critical. Based on what I saw, if they don't have to write something down, I would assume that they don't know what it is that they are doing. They have to articulate it, even more than doing experiments, because if they are technically gifted, they can usually do the physical work and be intellectually vacuous about what they're doing.

One mentor pointed out that writing the proposal helps students stay focused throughout the project and helps him see whether they understand what they are doing.

> I think it works out rather well. I mean I think it serves as a way to get them focused early on what they are doing. . . I think otherwise it would probably get really vague by the end. There's a chance of losing a lot of people who didn't quite, I mean it helps me understand whether they understand. And I imagine it helps them go around and gather up some of the background material they need to understand what they are about to try. So I'd hate to lose that. I think it's a good way of focusing.

3. Mentors generally did not actively direct the students' work in writing the proposal. They instead simply commented on drafts of the proposals, letting students take the lead in fulfilling this course requirement. Though all mentors felt that proposal writing was valuable, two mentors said that the formal hypothesis formation-and-testing structure of the proposal was not suitable for their students' project.

4. Though mentors felt that writing the proposal was an essential feature of the students' research experience, they were generally uninformed about the structure of the course. One mentor commented that his student "didn't ever talk to us about what she was getting from the course itself." Another mentor was unclear about what was expected of the students and thought the students were get conflicting comments on the proposals.

> Some of the things that I thought could have been done better, or at least that confused me and maybe that's just my misunderstanding of things. There seemed to be not much in the way of continuity in terms of what was expected of them. . . So they would get one set of comments back on, this is what you should be doing, and then the TA would get hold of what they had been doing and say no, no, no. And then of course I had my

> opinion. . . And that's probably inevitable, right? But I, I did feel for them because they were trying to please three or four masters at once.

B. Mentors felt the poster session provided students with a positive experience.

Several mentors attended the students' poster session. Though most mentors were not involved in producing the poster, they thought that the poster session provided the students with a positive experience. A few mentors described how proud their students were of their poster.

> Then when they were doing their poster, she was saying, "[The other student] and I are going to have the best poster. I know we are!"

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> And I went there and they looked pretty darn sophisticated. I mean they, you know, they stood next to the poster like they were proud of it and wanted people to look at it, they didn't look timid. I guess that's the first thing I noticed, they really wanted people spending time at their poster.

One mentor believed that the poster session helps give students a sense of closure and accomplishment even if their project did not reach firm conclusions.

> I think it's a sense of completing a project, even thought it's really somewhere kind of in the middle, but they've got something that they can pull together. This is where I think successful ownership really takes place, at this point in time, and I think that it probably takes until you get to this point for the vast majority of 152 students to figure out that they know what they did.

Another mentor saw the poster session as being an essential part of science: communication.

> Yeah, that's one of the brightest parts of science, of course, the communicating of what you've done to other scientists. So, it's probably just about the best way to cap off the course I can think of.

Though they thought the poster session was valuable, two of the mentors described the final drive to get results and produce the poster as "a big crunch" and "a frantic slapping together of things."

> I think actually what slowed them down was more the human factor of just setting things up and conflicts caused by final exams and things like that. I think they ended up with a big crunch at the end, you know, exams and other classes and insects to identify and stuff like that.

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> God, you know, I think they're valuable again, though I wish they'd had more time. You know, it's such a, a frantic slapping together of things.

Evaluators' Concluding Remarks

The students who participated in the directed research component of Botany/Zoology 152 described varied experiences that differed with respect to the nature of the projects they worked on, the laboratory culture they experienced, and the degree and type of guidance they were offered by mentors. Despite these variations, the students were unanimous in the belief that their research project was a valuable experience for them, and all termed it a success. Even the few students who experienced considerable difficulty with some aspect of their research project indicated that they did not regret their choice to conduct research rather than take the traditional course lab.

Students judged their research experience in relation to traditional science course laboratories. They reported that they experienced the real world of scientific research for the first time, and found it to be richly rewarding and far superior to science course laboratories. Students overwhelmingly felt that this experience enhanced and broadened the scope of their learning, particularly because it did not involve pre-planned experiments or simulations. They found themselves operating at a more independent level than they were accustomed to, and this challenged them and contributed to their gaining confidence.

We examined several components of the research project, including:

- the nature of the research project
- level of guidance from faculty
- interactions with peers, graduate students and others in the lab
- Botany/Zoology 152 lab meetings
- team versus independent work
- the team's organizational structure and working style

These components obviously did structure the particular experiences of individual students and might reasonably be expected to exert an effect on their perceptions of success. However, we could not perceive any strong patterns which would lead us to conclude that a particular variation within a given component was a determining factor in a successful research experience.

The evaluation's broad initial questions concerning team research were stated as follows:

- What is the nature of the team experience for undergraduates and faculty?
- Are there any characteristics unique to the team approach which are linked to success?

Because of the students' near-uniform perceptions of success and value, despite their differing situations, these initial questions did not receive simple answers. The nature of the team experience for both students and faculty varied considerably, with students within a given team offering differing perceptions. Teams varied in their organizational structure and working styles, and faculty mentors displayed different mentoring styles. Though team students and their mentors could cite advantages to the team approach, we found perceptions of success to be similar among team and individual research students. However, it should be noted that we are basing this finding on interviews with ten students from five teams and seven students working individually. Further study involving more team and individual students would be needed for confirmation.

Appendix: Interview Protocols for Students and Mentors

6

LEAD Center
Botany/Zoology 152 Team Research Evaluation
Research Students
Baseline Interview Protocol
May 5, 1995

Introductions

Explain why interview is being taped. Present "Informed Consent" form. Briefly review points from the consent form.

Questions

A. Background

1. Tell me a little about yourself [Probe: Where they are from (rural or urban; size of community or high school), why they came to UW-Madison].

2. What are you majoring in? What things have influenced you in choosing this major?

3. What biology courses have you taken in high school? As an undergraduate?

4. Have you taken the course "Ways of Knowing Biology" or "Ways of Knowing" (a freshman seminar course)?

If yes: We are interested in your impressions of that class.

B. Current Course Questions

1. How did you find out about the biology courses that are offered? [Probe: SOAR, friends, faculty] (Biology courses include Zoo/Botany, 151/152, Zoology 101 and 102, and Biocore)

2. A. Why did you decide to take the 151/152 course sequence?

   B. How does Biology 151/152 fit into your academic or career plans?

3. Did you know prior to registering for 151/152 that this course had an independent research option? How important was the independent research option to you?

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4. Tell me how you feel you are doing in the course overall?

Labs

1. Tell me about the 151 labs.

2. Do you work alone, with a lab partner, or in groups?

   If they work with lab partner or group: Describe how you work as partners or in a group?

3. Which do you prefer, working alone, with a partner or in a group? Why is that?

   If no contrast: What do you like about working in a group (with a partner)? What do you dislike about working in a group (with a partner)?

4. Have you ever worked in a group science project in high school or in a summer program? Could you give me an example and tell me a little bit about that experience. **Do you think this is how scientists really work?**

C. Research Project Experience and Expectations

1. You chose (independent research)(modular lab) for the research project in 152, why did you make that choice?

2. How did you come up with a list of researchers in your interest area? [Probe: Impression of the process].

3. You will be working (one-on-one)(in group research). Describe how that happened? How do you feel about that?

4. Did it matter to you whether you worked one-on-one or in a small group? Why is that?

   For Group Option Only:
   4a. Do you have any thoughts on what it will be like to do research as a group?

5. What are your thoughts about working with the researcher?

6. What do you want to get out of this research experience?

7. Is there anything in particular that you are hoping to learn? [Probe: Process vs. Content; Experience vs. Content].

8. Have you ever considered becoming a scientist? Why or why not?

9. What are the characteristics of a person who chooses science as a career path? Is this like or not like you?

E. Concerns

1. What concerns, if any, do you have about this research experience?

2. Do you have any questions or comments that you would like to share with me?

LEAD Center
Botany/Zoology 152 Team Research Evaluation
Traditional Lab Students
Baseline Interview Protocol
May 5, 1995

Introductions

Explain why interview is being taped. Present "Informed Consent" form. Briefly review points from the consent form.

Questions

A. Background

1. Tell me a little about yourself [Probe: Where they are from (rural or urban; size of community or high school), why they came to UW-Madison].

2. What are you majoring in?

3. What biology courses have you taken in high school? As an undergraduate?

4. Have you taken the course "Ways of Knowing Biology" or "Ways of Knowing" (a freshman seminar course)?

   If yes: We are interested in your impressions of that class.

B. Current Course Questions

1. How did you find out about the biology courses that are offered? [Probe: SOAR, friends, faculty.] (Biology courses include Zoo/Botany, 151/152, Zoology 101 and 102, and Biocore)

2. A. Why did you decide to take the 151/152 course sequence?

   B. How does Biology 151/152 fit into your academic or career plans?

3. Did you know prior to registering for 151/152 that this course had an independent research option?

4. Tell me how you feel you are doing in the course overall?

C. Lab Questions

1. Tell me about the 151 labs.

2. Do you work alone, with a lab partner, or in groups?

   If they work with lab partner or group: Describe how you work as partners or in a group?

3. Which do you prefer, working alone, with a partner or in a group? Why is that?

   If no contrast: What do you like about working in a group (with a partner)? What do you dislike about working in a group (with a partner)?

4. Have you ever worked in a group science project in high school or in a summer program? Could you give me an example and tell me a little bit about that experience? **Do you think this is how scientists really work?**

D. Research Project Experience and Expectations

1. You chose the modular lab for the research project in 152, why did you make that choice?

2. What do you think it will be like to do the modular lab? [Probe for expectations of a modular lab.]

3. A. Is there anything in particular that you are hoping to learn?

   B. What do you want to get out of this research experience? [Probe: Process vs. Content; Experience vs. Content]

4. Do you think you will pick a research experience later on in your college courses? Why is that?

5. Have you ever considered becoming a scientist? Why or why not?

6. What are the characteristics of a person who chooses a career path in science? Is this like or not like you?

E. Concerns

1. What concerns, if any, do you have about the lab portion of 152?

2. What concerns, if any, do you have about your biology experiences at the UW?

3. Do you have any questions or comments that you would like to share with me?

LEAD Center
Botany/Zoology 152 Team Research Evaluation
Mentors
Baseline Interview Protocol
June 7, 1995

Faculty Background

1. Tell me a little about your career and how you came to be in your present position. [Probe: Length of time at the UW?]

2. Have you ever worked with undergraduate students in your lab before?
   [Probe for experiences with undergraduates who have worked in their lab i.e.
      How many students per year?
      How long has each student stayed in the lab?
      What year of school were they?
      Did they start as glassware washers?
      Did they start as part of a project such as Senior Thesis or Hilldale Fellowship?]

Research Project Motivation

3. Why do you involve undergraduates in your research lab? Generally, do your colleagues feel the same way as you do? Why or why not?
   [Probe: In your opinion, should students have research experience as undergraduates? If yes, which students and why?]

   A. Did you have research experience as an undergraduate?

4. What prompted you to become involved in the 152 Research Project?
   [Probe for personal research experiences.]

5. **For Group Experience Only:**

   A. Why did you decide to work with a team of undergraduate students in your lab? [Probe for pervious experiences working with a group of undergrads in lab.]

Role of Faculty and Staff

6. How are you going to structure the way these students work together?
   [Probe: Working on a task together versus separate tasks; Group proposal versus individual proposal, final report?]

7. What will be your role in this research experience?

    A. What preparation will you do or have done to get ready for the fall?

8. What will be the role of staff in your lab in this research experience?

    A. How will the staff decide what the student(s) will do?

    B. What will their day-to-day interaction with the student(s) be?

    C. How does your lab operate in general? [Probe for interactions between graduate students, staff and lab organization such as weekly meetings, group projects, etc…]

9. What are your expectations/goals for this student research project? Is there anything in particular that you are hoping the student(s) will learn?

    A. **For Group Experience Only:**
    Are there any differences in your expectations in working with a group versus individual students?

10. What will be [should be] your criteria for evaluating the students in this research experience?

Closure

11. Do you have any important concerns or issues about having undergraduates in your lab?

12. What is the role of collaborative work in your field of research?

LEAD Center
Botany/Zoology 152 Team Research Evaluation
Non-Participating Faculty
Baseline Interview Protocol
July 5, 1995

Faculty Background

1. Tell me a little about your career and how you came to be in your present position. [Probe: Length of time at the UW?]

2. Have you ever worked with undergraduate students in your lab before?
   [Probe for experiences with undergraduates who have worked in their lab, i.e...
      Did they start as part of a project such as Senior Thesis or Hilldale Fellowship, 152 Students, CALS, Honors? etc...
      How many students per year?
      How long has each student stayed in the lab?
      What year of school were they?
      Did they start as glassware washers?]

Undergraduate Research Projects

3. Why do you involve undergraduates in your research lab? Generally, do your colleagues feel the same way as you do? Why or why not?
   [Probe: In your opinion, should students have research experience as undergraduates? If yes, which students and why? Is class standing a factor?]

   A. Did you have research experience as an undergraduate?

4. Have you ever had more than one undergraduate student working in your lab?

   If NO:
   A. Is there a particular reason why?

   If YES:
   A. Have they ever worked together on a project?

   B. Would you ever consider working with more than one student on a group type project? Why or why not? [Probe for class standing as a factor.]

Role of Faculty and Staff

6. What is your role in these undergraduate research experiences?

7. What is the role of the staff in your lab in working with undergraduates?
    - A. How does the staff decide what the student(s) will do?
    - B. What is their day-to-day interaction with the student(s)?
    - C. How does your lab operate in general? [Probe for interactions between graduate students, staff and lab organization such as weekly meetings, group projects, etc…]

8. What are your expectations/goals for students in a research project? Is there anything in particular that you are hoping the student(s) will learn?

9. What is your criteria for evaluating the students in this research experience?

Closure

10. Do you have any important concerns or issues about having undergraduates in your lab?

11. Do you notice differences in working or learning styles of undergraduate students who have done research projects in your lab? [Probe for students approach to projects.]

12. What is the role of collaborative work in your field of research?

LEAD Center
Botany/Zoology 152 Team Research Evaluation
Mid-Semester Student Interview Protocol (10/95)

1. How did you wind up working in this lab?
   (Description of process of selection. Intimidating?)

2. a. Could you describe your project and what you are doing?
   (Do you like your project?)

   b. Compare your experience of working on a research project with the 151 labs or other labs you have had?
   (Simulation vs real science.)

   c. How important, do you think, is the question you are working on?
   (To the student, mentor, world.)

3. a. Describe to me what it is like working on your project - what exactly do you do when you come into the lab?

   b. How many hours per week do you put into it?
   (Is scheduling individual/team work a problem?)

4. a. Tell me more about how you are being guided through this project.
   (Faculty, graduate student? Role of supervisor, amount of contact.)

   b. Are you satisfied with this level of guidance?

5. a. What was it like getting started?
   (Did you feel prepared to tackle this project?)

   b. How did you decide on a project?
   (Who decided? How?)

   c. Were goals, expectations, and a time line discussed?
   (By whom? Were you involved in setting these goals and expectations?)

   d. Were there any techniques you had to learn?
   (Describe these. Time spent learning?)

   (Team question) e. Did you work with your group in learning these techniques?

6. a. Tell me about the process of writing a proposal.

b. Did you learn anything from writing this?
(Were there any difficulties? Done as a team?)

Team Questions:

7. Describe working with your group.
(What exactly do you do together or separately? Who decided on how your group was going to interact?)

8. a. How do you feel about working in a group?
(Team members, working styles, common goals)

b. Would you prefer working on this project independently rather than in a group?

Individual Question:

9. How do you feel about working individually?
(Would you prefer working on this project with a group of other students?)

10. a. Tell me about the other people working in the lab.
(What is your relationship with them?)

b. Who do you go to when you have a question?

c. Do you feel like you are part of the lab?
(Do you fit in? Identity, see self within the culture, a home on a large campus, entree for career.)

11. a. Are there group lab meetings? Do you attend?

b. Could you describe them?

c. Do you participate?

12. a. Can you describe what you and the other students do at the 152 class meetings?
(Peer reviews of proposals? How important are these - are they helping you through this?)

b What does your 152 TA do?

13. a. What are you getting out of this experience so far?

b. How does your experience compare with what you expected?

c. What is the most striking thing you have learned so far?
(Knowledge, process of science, human relations.)

A question for students previously interviewed:

14. I've selected some interesting passages from your first interview. I would like for you to look at them and comment on what you said before. Here is the first one.

15. a. So has this experience been successful for you so far? Why or why not?
(Level of confidence, sense of accomplishment, motivation)

b. How would you improve your experience?
(If you were in charge, would you have handled this differently?)

16. What do you think the grade for this independent project should be based on?

17 Do you have any questions or comments?

LEAD Center
Botany/Zoology 152 Team Research Evaluation
Student Final Interview Protocol (1/96)

1. Could you describe what you did in your project for us? (Results and conclusions?)

2. In general, do you think you had a successful experience? Please explain. (How do they define success? What accounts for their feeling - nature of project, match with abilities, lab culture, mentor.)

2a. Did you feel this throughout the project or was there a change over time? (Refer to previous interview.)

2b. What do you think was the most important factor in making your experience a success? (Nature of project, lab culture, mentor)

3. How difficult do you think your project was? Explain. (Theory, complexity of lab work.)

3a. How well do you think you understand what you did?

Team questions:

4. Describe what you did working with the other Biology 152 student(s).

4a. Do you think that you worked together as a group or team? Explain. (What do together or separately, how they split work, amount of interaction, efficiency, distinct roles.)

4b. How did it go? (Advantages. What were some good things? Some bad things? Personalities, working styles, productivity.)

4c. Even though you did not work in the lab at the same time, did you feel that being with another student helped you? Please explain.

5. Would you have preferred working on this project independently rather than in a group? Please explain.

6. Did you get to feel like you were part of the lab, that you fit in? (Reasons for feelings: social interaction, scientific understanding, technical competence, contribution.)

6a. What factors made you feel that way?

6b. Did you want to be part of the lab group?

6c. Does this type of work appeal to you? (Are you like or not like the other people in the lab?)

7. Did you meet regularly with your mentor? What did you do in the meetings? (Whole group attend? Amount of guidance?)

8. What did you get out of this research experience? (Many types of possibilities: technical knowledge, confidence, accomplishment, discipline and commitment, interest in science, understanding of process of science, sense of identification with the lab and its people, entree into science, visualization of a place for them.)

8a. Has this experience changed you? (Affect what you are going to do in courses, your major, career plans?)

9. How did your experience compare with your expectations?
(Did anything turn out to be surprising or unexpected?)

9a. How does this research experience compare with your other science courses and labs that you had this semester? (Did you experience a sense of development during this semester, perhaps an adaptation from classroom to research?)

10. When we talked to you last, you had just revised your proposal. Did you do a final paper based on it?

10a. Was the proposal and paper worth doing? Why? (Build relationship with mentor.)

11. What did you think about the poster session? (Provide closure?)

12. Do you feel like you were doing science? Why or why not?

12a. What do you think doing science is?

12b. Has your view of science been changed by your research experience? (Can you compare your ideas of science before your research experience with what you think now?)

13. If you were (name of mentor), would you have done things differently? Explain.

14. Do you have any advice for future research students, something you would want to tell them to make their experience better?

15. Would you want to do more research? Explain. (With this professor? Explain.)

16. Is there anything more you would like to talk to us about - your concerns or good things that happened?

Questions from reading their and the mentor's interviews:

LEAD Center
Botany/Zoology 152 Team Research Evaluation
Team Mentor Final Interview Protocol (1/96)

Note: Read the faculty member's initial interview and the students's interviews and write notes for probes under the relevant questions.

1. Your Biology 152 research students were (names). Could you tell me what they did this semester?

2. How did you come up with the project they did - or did the students decide?

    2a. Did this project further your own research or was it designed specifically as an educational experience? (Goals of the project? Do you think the students were doing science? Explain.)

3. How did you get them started on the project?

    3a. Did you talk about goals and expectations with the students? Please explain. (Did you discuss a time line?)

4. The idea initially described to you by Jill Patterson was to have more than one Biology 152 student together in a lab setting. How did this work out?

    4a. Do you think your students worked as a group or team? Please explain.

    4b. Do you think there was an advantage for them working as a group as opposed to working as individual students? Please explain. (Advantage for mentor, advantage for students.)

5. How would you describe your role in their experience?

    5a. Did anyone else in your lab act as a mentor? (Describe how you interacted with other people in your lab in coordinating the students' project.)

6. What do you think of the proposal writing requirement? (Its purpose? How much were you involved in this?)

    6a. What did the students get out of writing the proposal? Did you have the students work together on it?

    6b. If you were the course organizer, would you have this as a requirement?

7. Did the undergraduates interact with other lab people? Explain. (Did they fit into the lab, feel comfortable there?)

7a. Do you think that is important? (Aside from the 152 students, do faculty consider lab culture important?)

8. Did you meet regularly with the undergraduate group? Could you describe the meetings?

8a. Does your research group meet regularly? Did the undergraduates attend?

9. Considering the amount of time and resources your lab spent this semester, do you think it was worth it? (What did you get or want to get in return?)

9a. How much of your and your staff's time did this take?

9b. Would you do it again?

9c. Will any of the students continue to work in your lab?

10. Would you do anything differently if the students could begin the project over again? (Or - What would you do differently the next time around?)

11. Was this research experience successful? (Research outcomes, educational outcomes?)

11a. What do you think the students got out of, or learned from, their research experience? (What do you think is the most important thing?)

11b. Was the theoretical level of the project or the complexity of the laboratory work a problem for the students? Explain. (In most cases students are in the second semester of their first biology course. How much understanding is necessary?)

11c. Did you see any change or development in them over the semester? (Level of independence?)

12. If you could only pick one or two characteristics that you think important for undergraduate research students to have, what would you pick - i.e., why are some students successful and others are not? (This was the students first biology course. Did this matter?)

13. Were you able to attend the poster session? What did you think about it? (Value to students in providing closure?)

14. Is it important for you to receive supply money for this project?

15. To summarize your thoughts, how would you describe an ideal successful research experience for undergraduates?

16. Do you have any suggestions for improvement for the course coordinators?

17. As far as getting other faculty members interested in being undergraduate research mentors for a group of two or 3 undergraduates at a time, what aspect of doing this would appeal to them? Or perhaps you have some ideas for another model?

LEAD Center
Botany/Zoology 152 Team Research Evaluation
Non-Team Mentor Final Interview Protocol (1/96)

Note: Read the faculty member's initial interview and the student's interviews and write notes for probes under the relevant questions.

1. Your Biology 152 research students was (name). Could you tell me what he/she did this semester?

2. How did you come up with the project he/she did - or did the student decide?

    2a. Did this project further your own research or was it designed specifically as an educational experience? (Goals of the project? Do you think the student was doing science? Explain.)

3. How did you get him/her started on the project?

    3a. Did you talk about goals and expectations with the student? Please explain. (Did you discuss a timeline?)

4. How would you describe your role in his/her experience?

    4a. Did anyone else in your lab act as a mentor? (Describe how you interacted with other people in your lab in coordinating the student's project.)

5. What do you think of the proposal writing requirement? (It's purpose? How much were you involved in this?)

    5a. What did the student get out of writing the proposal?

    5b. If you were the course organizer, would you have this as a requirement?

6. Did the student interact with other lab people? Explain. (Did he/she fit into the lab, feel comfortable there?)

    6a. Do you think that is important? (Aside from the 152 students, do faculty consider lab culture important?)

7. Did you meet regularly with the student? Could you describe the meetings?

    7a. Does your research group meet regularly? Did the student attend?

8. Considering the amount of time and resources your lab spent this semester, do you think it was worth it? (What did you get or want to get in return?)

8a. How much of your and your staff's time did this take?

8b. Would you do it again?

8c. Will the student continue to work in your lab?

9. Would you do anything differently if the student could begin the project over again? (Or - What would you do differently the next time around?)

10. Was this research experience successful? (Research outcomes, educational outcomes?)

10a. What do you think the student got out of, or learned from, his/her research experience? (What do you think is the most important thing?)

10b. Was the theoretical level of the project or the complexity of the laboratory work a problem for the student? Explain. (In most cases students are in the second semester of their first biology course. How much understanding is necessary?)

10c. Did you see any change or development in him/her over the semester? (Level of independence?)

11. If you could only pick one or two characteristics that you think important for undergraduate research students to have, what would you pick - i.e., why are some students successful and others are not? (This was the students first biology course. Did this matter?)

12. Were you able to attend the poster session? What did you think about it? (Value to students in providing closure?)

13. Is it important for you to receive supply money for this project?

14. To summarize your thoughts, how would you describe an ideal successful research experience for undergraduates?

15. Do you have any suggestions for improvement for the course coordinators?

16. As far as getting other faculty members interested in being undergraduate research mentors, what aspect of doing this would appeal to them?

16a. Or perhaps you have some ideas for another model?

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